REPORT ON THE WATER-POWER

OF THE

REGION TRIBUTARY TO THE MISSISSIPPI RIVER

ON THE WEST, BELOW DUBUQUE, IOWA,

BY

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BOSTON, MASS., *July* 9, 1883.

Professor W. P. TROWBRIDGE,
Columbia College, New York City.

SIR: I have the honor to submit a report upon the water-power of the region tributary to the Mississippi river on the west, below Dubuque. The country thus embraced is of vast extent, and is traversed by numerous long and rapid streams; but, owing to certain features of surface and climate, these streams do not in general offer large available water-powers. The great area which they collectively drain has within recent years been encroached upon by settlement and improved by cultivation at a most wonderful rate; but, as is natural in the earlier stages of development, manufacturing industries have not yet been largely introduced, and the demand for power is still limited. Nevertheless, where it has arisen, as in the case of flouring-mills, almost the sole users of water-power beyond the Mississippi, the streams have very generally been put to service, and at scattered points, such as Cedar Rapids, Sioux Falls, Lawrence, Arkansas City, and others, the development of powers of considerable relative importance has been undertaken.

The examinations upon which this report is based were carried on under your direction during the winter of 1880–'81 and a part of the following spring. Various difficulties were encountered, arising from the rigor of an unusually severe winter, the lack of convenient railroad communications, and the paucity of recorded data such as might be found in a section of older settlement; but sufficient information was perhaps gained to give a fair idea of the characteristic features of the principal streams and their capabilities for supplying power. The same system of estimates elsewhere followed in my reports, and explained in detail in connection with the report upon the region tributary to Long Island sound, has here been continued.

Very respectfully,

DWIGHT PORTER,
Special Agent.

REGION TRIBUTARY TO THE MISSISSIPPI RIVER ON THE WEST, BELOW DUBUQUE.

I.—THE MISSOURI RIVER BASIN.

GENERAL CHARACTERISTICS.

1.—Position and extent.

The area included within the water-shed lines of the Missouri river comprises a great tract of country lying, in the main, northwest of the center of the United States. It stretches from the more immediate basin of the Mississippi, on the east, westward to the main ridge of the Rocky mountains; on the south is the Arkansas river, while to the north it extends into the British Possessions, and is limited by the basins of the Saskatchewan and Assiniboine rivers. It lies approximately between the parallels of 37° and 50° north and the meridians of 90° and 114° west, and measures about 527,000 square miles, distributed as follows:

	Square miles.
British Possessions	15,000
Montana	121,800
Wyoming	71,800
Dakota	115,500
Minnesota	1,700
Colorado	29,600
Nebraska	77,000
Iowa	17,400
Kansas	40,600
Missouri	36,600
	527,000

In regard to its location, perhaps the most important facts to be noted are that it is on the leeward side of a chain of high mountains and is remote from any large body of water. At the nearest approach its boundaries are, in round numbers, 250 miles from the great lakes, 500 miles from the Gulf of Mexico, 500 miles from the Pacific ocean, and 600 miles from Hudson bay. In consequence of this land-locked position, it follows that a wind from any quarter must be robbed of much of its moisture before it can reach even the confines of the Missouri basin.

2.—The mountainous section.

The region which we are considering may, for convenience, be divided into two parts—the mountainous district and the prairies—the former of which I shall first describe. Entering the United States from British America, the great range of the Rocky mountains passes down with a southeasterly trend, its main ridge forming the divide which separates those streams flowing ultimately into the Atlantic from those which reach the Pacific. On either side of this ridge, or "backbone of the continent", are many minor ranges and spurs, which extend the mountainous section a long distance east and west. In Colorado it lies mainly west of the 105th meridian, but in southwestern Dakota the Black Hills carry its limits nearly two degrees farther east.

The resources of this division of the Missouri basin are almost incomparable. Scattered over nearly its entire extent are deposits of gold, silver, iron, copper, and coal, of unknown magnitude. The mountain slopes are densely covered with pine, spruce, and cedar. As much as one-eighth of Montana territory and nearly one-third of Wyoming are said to be timbered. Neither is this section without agricultural value; scattered among the mountains and situated along the river-courses are many large tracts of prairie land, finely adapted to grazing or cultivation. Of the combined area of Montana and Wyoming 30 per cent. is stated to be mountainous; a total of 45 per cent. is regarded as suited to grazing, and 15 per cent. to cultivation.

The average elevation of Montana above the sea is given as about 3,900 feet, of Wyoming 6,400 feet, and of Colorado 7,000 feet. Above these general levels there rise the mountain peaks, which attain altitudes of 10,000 to 16,000 feet above the sea. On some of these snow is found in considerable amounts, even throughout the summer, while on all it is retained long after it has disappeared from lower levels. It thus serves, to a certain extent, as a reservoir for maintaining the flow of the mountain streams. After the snow has disappeared, however, the steep, rocky slopes of the mountains quickly shed the heavy summer rains, and cause rapid oscillations in the streams.

A general similarity is to be seen in the streams which drain the mountain slopes. They descend rapidly, and in their courses through the mountains have often cut their way down to great depths, forming narrow cañons with almost vertical sides. They present certain advantages, and certain disadvantages, to use for power. Their low-water volumes are, as a rule, too small to furnish powers of magnitude, and their valleys are much of the way too narrow to afford convenient sites for building. In the wildest portions of the cañons the rocks rise up almost vertically from the water's edge to heights of 500 to 2,000 feet.

The mountain valleys do, however, widen out at intervals so as to give sufficient room for building purposes. The beds and the banks of the streams, being of solid rock, offer the best of foundations for dams, and the rapid fall renders it possible to make up somewhat for the lack of volume by increased head. The courses of the streams are the only practicable routes for railroads to follow into the mountains, and so in one or two cases, such as the north fork of the South Platte and Clear creek, we find railroads thus built, but usually the mountain streams are destitute of railroad facilities. They are subject to sudden rises at times, but the larger streams are seldom so affected as to be dangerous to properly located establishments. A few lakes of small size are found among the mountains, and might probably be improved for storage. On issuing from the foot-hills these streams are, in most instances, drawn upon for irrigation, which is of much more importance there than any use for power.

3.—The prairie section.

The second great district to be noted in the Missouri basin comprises the prairies, which stretch eastward from the Rocky mountains like a vast sea. They, of course, present varying features, according to their location, some being much more fertile and better cultivated than others, but the following description by Captain William Ludlow will convey a good idea of the less favorable portions of Dakota:

(*a*) The Dakota prairies have been often described, but their general characteristics may be briefly stated: A rolling, and at times a hilly country, destitute of wood, except small quantities in the eroded valleys of streams, and covered with short grass. The horizon, bounded everywhere by the undulating outlines of the surface, and varied occasionally by some more dominating elevations, which constitute the landmarks of the traveler, and are called buttes. The summer sun shines from a generally cloudless sky, the purity of the air gives its rays great power, and the thermometer frequently rises above 100° in the shade.

Water is scarce, and almost invariably alkaline, even in running streams, from the presence of a salt which forms a component of the clayey soil. The rivers are small streams, of great comparative length, which, from absorption and evaporation, shrink in their downward course, and are frequently dry at their mouths, while flowing freely a hundred or two miles above. The seasons of spring and fall are exceedingly brief. The winter snows are rapidly disposed of in the spring, and rainfalls are unfrequent until cold weather in the fall, which soon again merges into winter. By July 1 the grass is full grown, and in another month has turned dry and yellow, cured to hay upon the ground and readily burned.

The great expanse of the prairies has a gradual slope, imperceptible to the eye, toward the east. Denver, which is but a short distance from the foot-hills of the Rocky mountains, is about 5,300 feet above sea-level; advancing directly to the east from this point, we reach the Missouri river, near Atchison, at an elevation of about 800 feet. In this interval of 520 miles there has been an average descent, slowly decreasing in rate, of approximately 8½ feet per mile for the entire distance. This considerable surface slope has the effect of giving the streams a rapid fall, and also secures a good drainage to the soil.

4.—Geology.

All evidence points to the fact that for long periods in geological history the prairies of the Missouri basin lay at the bottom of an inland sea. In the Tertiary period this sea extended from Texas northward into British America, and stretched from the foot-hills of the Rocky mountains eastward beyond the present Missouri river. On the bed of this sea were laid the Pliocene deposits of the Tertiary.

In the Champlain period this sea appeared contracted in size, and over the Tertiary deposits left its burdens of transported Drift. In still later times, when the inland sea had taken on more the appearance of a chain of great lakes, extending along the course of the present Missouri river, the Drift of this section was in turn buried beneath a deposit of Loess.

The Pliocene deposits of the Tertiary form the surface materials in western Nebraska, and are found in northwestern Kansas, extending thence into Colorado. As stated by Professor Samuel Aughey, they are nearly 2,000 feet thick along the foot-hills of the mountains in Colorado. In that vicinity the material of these deposits is exceedingly coarse, and is largely composed of conglomerates. On the south side of the Republican, in Harlan county, Nebraska, Professor Aughey found it made up largely of lime mingled with siliceous materials, and on the Driftwood, south of the Republican valley, it consisted of loosely-compacted sand and pebbles underlaid by limestones and marls.

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a Report of a Reconnaissance of the Black Hills of Dakota, 1874.

In northwestern Kansas, Professor Mudge remarks that—

> The material of the Pliocene deposits consists of sandstones of various shades of gray and brown, occasionally whitened by a small admixture of lime. The lower strata are usually composed of finer sand than the upper, and are looser and more friable in their texture. The overlying beds are of coarser ingredients, consisting of water-worn pebbles of metamorphic rocks.

East of the region just described is found the Drift, overlying the Tertiary, and composed as elsewhere of clays, gravels, sands, and bowlders. In Nebraska it ranges in thickness from a few inches to 75 feet, and in Kansas is about 5 feet thick, occasionally increasing to 20 feet. The smaller pebbles and gravel of the Drift occur in Kansas as far south as latitude 38°. The material of this formation is widely diffused in Nebraska, but is seldom exposed in large areas on the surface, usually being covered by later deposits.

The Loess, or Bluff deposit, is met with overlying the Drift, and forming the surface material over a large portion of the country neighboring to the Missouri river. It is supposed to have been deposited in the beds of the old lakes which, at some time, stretched along the course of the Missouri, then, as now, a very muddy stream. I do not know that the entire boundary of this deposit has been accurately defined. Dr. C. A. White has shown clearly its eastern limit in Iowa, where it extends, at the farthest, 50 or 60 miles from the Missouri. In southwestern Iowa it attains a depth of 150 and even 200 feet.

Professor Mudge states that in Kansas the Loess has a thickness of nearly 125 feet at Wyandotte, on the Missouri river, gradually thinning out to the westward till, 100 miles away, it almost disappears. It is said to prevail over at least three-fourths of Nebraska, ranging in thickness from 5 to 150 feet.

The influence of these geological formations on the value of the streams for water-power is important. The Loess is very permeable to water, so that rains falling upon its surface readily penetrate it. Its composition is almost precisely the same in all localities and at all depths, and water percolating through it will sink steadily until some impervious stratum is encountered in the underlying Drift. It may thus sink much below the beds of the streams, and fail to appreciably increase their volume. Some of the streams flowing over the Loess have cut their way down to the Drift, and receive the benefit of the water arrested by that deposit; most, however, have not succeeded in doing this, and suffer in consequence. The Loess material is fine, black, and siliceous, and the streams running over it are characterized by muddy beds and banks, entirely unsuited to dams of ordinary construction, and rendering necessary, in many cases, structures of brush.

The Drift deposit is well supplied with springs, so necessary to the maintenance of a good low-water volume, and occasionally offers firm gravelly beds for dams. Underneath the surface deposits of Drift and Loess are found sandstones and limestones, many of which are of the finest quality for building purposes. Some of the streams, such as the Blue river of Kansas and Nebraska, have cut their channels, at points, down to these strata; but, in general, the river beds are either muddy or sandy.

The effects which the Loess and Drift deposits would naturally have elsewhere upon the flow of the streams are modified here, from the fact that much of the rain falling upon the surface of the ground is unable to penetrate it at all. It must be remembered that the prairies of which we are now speaking are nowhere level, but everywhere present a rolling surface, which easily sheds water. Although they are covered with grasses, timber is extremely scarce, and west of the 98th or 99th meridian is seldom seen at all. From the report of the Kansas state board of agriculture it appears that only about 5 per cent. of the entire surface of that state is timbered. The ground, thus bare, has been exposed, for ages, perhaps, to scorching suns, dry winds, pelting rains, and a pounding by the hoofs of myriads of wild animals, till it has become almost impervious to water. Under these circumstances, rains which otherwise would gradually sink down through the soil are shed almost immediately into the streams, and render them very unsteady.

A valuable remedy for this evil is in the increased cultivation of the soil, which breaks it up and renders it receptive of water. The benefits thus derived by the streams do not admit of doubt. Professor Aughey, in his *Sketches of the Physical Geography and Geology of Nebraska*, gives the results of his own observations upon the formation of new springs and the increase in volume of small streams. In Kansas I took especial pains to inquire into the same subject, and received everywhere uniform testimony; on the Republican, Solomon, Smoky Hill, and in other parts of the state these phenomena have been observed. New springs have made their appearance, and small streams which fifteen years ago ran dry during a part of the year, now always contain running water, and have extended their low-water courses considerable distances back up their valleys. These effects have been especially marked in the Republican valley. In Cloud county, Kansas, on the divide between the Republican and Solomon rivers, water could not formerly be reached in borings, even at a depth of 100 feet, but it is now readily obtained 25 feet below the surface.

5.—General features of the prairie streams.

The streams which drain the prairies display numerous points in common. So far as regards their capabilities in the way of water-power, they may be said, in brief, to present many unfavorable features, while they at the same time offer some advantages. They do not exhibit abrupt falls, but descend with a uniform slope, frequently amounting, in their upper courses, to several feet per mile. Although the dams do not usually throw the water

back so as to flood beyond the banks, the backwater extends far enough up stream to really give a very considerable storage. Where the streams are able to carry off their flood-waters without overflowing, they admit of a very thorough utilization of their power, since they may be improved with almost equal facility at all points. Again, the level bottom-lands which border them offer the most practicable routes for railroads, and, consequently, we find a great many streams skirted closely by finely-equipped lines.

On the other hand, the beds and banks are, as I have elsewhere said, very unfavorable to the security of dams. Where not muddy they are generally sandy, and are frequently composed of a very treacherous quicksand, as in the Republican and the Platte. The head to be obtained is, in general, no more than the lift of the dam. The bottoms bordering the streams range from 1 to 3 miles in width on the smaller ones, and are sometimes two to three times as wide on the larger rivers. They have nearly a level surface at right angles to the streams, and parallel to them a slope nearly coincident with their own. Now and then a river approaches the bluffs on one side, but quickly winds back to the opposite side of the bottom. It is, therefore, impracticable to gain head by use of a canal, except by gradually raising it above the level of the bottom by diking on either side—a construction which has many disadvantages, and which has seldom been adopted on these streams.

A very great objection to the prairie streams is their variability in volume, and the low stage which they reach in certain seasons, notably in late fall and winter. The larger manufacturing streams of the Atlantic slope seldom show a less rate of discharge than 0.30 to 0.50 cubic foot per second to the square mile of drainage area; while there are probably few of those which we have been considering that do not, at some period of the year, fall below a discharge of 0.05 to 0.10 cubic foot per second to the square mile, and some even entirely dry up, or become a chain of stagnant pools. The Kansas river had a volume at Topeka, in the winter of 1874–'75, corresponding to only 0.035 cubic foot per second to the square mile. During the month of October, 1879, the Missouri river itself, with its drainage area of more than 500,000 square miles, showed an average discharge of only 0.0568 cubic foot per second per square mile. From these very low stages the rivers we are considering rise, usually in early summer or midsummer, to relatively very high points. The wider and more rapidly falling usually succeed in carrying off their flood volumes without overflowing their banks; but the narrower and more sluggish ones, for example those of the western Iowa and northern Missouri slopes, spread out far and wide over the bottoms, sometimes reaching widths of 1 mile to 3 miles.

Measurements of flow made at Saint Charles, (*a*) near the mouth of the Missouri river, during the year 1879, presented a variation in volume from 26,446 to 298,537 cubic feet per second, or a range from 0.0502 to 0.5665 cubic foot per second to the square mile of drainage area. From these observations it was inferred that the ordinary range of flow, from low to high water, would be approximately from 15,000 to 430,000 cubic feet per second, or from 0.028 to 0.816 cubic foot per second to the square mile. At this rate the high-water discharge would be nearly thirty times that at low water, and with many smaller streams the disproportion would doubtless appear a great deal more.

In some sections, where Drift constitutes the surface material, many small lakes, technically known as Drift lakes, are met with. They are to be found in Dakota, and there are a few within the limits of the Missouri basin in Iowa. Some have a direct connection with the streams, while a large proportion of them are apparently isolated. They are all probably of some value in maintaining the flow of neighboring streams, either by surface connection or by underground percolation; and where sufficiently numerous and large, as in the Big Sioux basin, in Dakota, they might be made available for increased storage.

Storage of magnitude in artificial reservoirs, so frequently used in New England, is not, however, generally practicable with prairie streams. There are few natural lakes or ponds, except in the limited sections just noted. The positions of the streams, in the midst of broad and fertile bottoms, often seemingly as level as a floor, and seldom approached simultaneously from both sides by the bluffs, would prevent the formation of extensive reservoirs on their courses, unless at great and unbearable expense. Along the foot-hills of the Rocky mountains there are, undoubtedly, numerous depressions which were at some period in the past occupied by small lakes, and which might, at a reasonable outlay, be made available for storage; in fact, this has been done already in a few cases, not with a view to using the stored water for power, but for irrigation. Even if artificial reservoirs should be constructed on the prairies, a great disadvantage would be encountered in the extreme evaporation. On the northern Atlantic slope from 40 to 60 per cent. of the rainfall may be realized; but for the entire Missouri basin Humphreys and Abbot give the ratio of drainage to rainfall as only 15 per cent. At Milford, in northwestern Iowa, power is used at the outlet of Spirit and Okoboji lakes, and I am informed by Mr. T. S. Seymour, secretary of the water-power company, that only a little more than one-eighth of the annual rainfall is counted on there. Storage reservoirs would, perhaps, benefit the prairie streams relatively as much as they do those of the east; but when it is considered that the average rainfall for the entire Missouri basin is only about 20 inches, against 45 inches, more or less, for the north Atlantic slope, and that, of the rain which does fall, only one-third to one-fourth as much can be realized in the former region as in the latter, it is evident that the absolute gain in volume of the streams would be small compared with that obtained by eastern manufacturers from their rivers.

a See *Preliminary Report* by Major Charles R. Suter.

6.—Climate.

The healthfulness of the climate of the Missouri basin is famous and unquestioned. There are, doubtless, some low valleys in the state of Missouri where fevers and malaria are prevalent, but the high ground is perfectly healthy, and as we advance westward over the prairies, and especially as we approach the mountains, the air is found to be remarkably dry and bracing. Owing to the remoteness of large bodies of water, extreme changes of temperature are not uncommon, but they are much less noticed than in the moister atmosphere of the East.

Temperature.—The following records of temperature are principally from the Smithsonian tables. A number of places well scattered over the Missouri basin are included, and there are also added records of one point in the Gulf states and one in New England. The maxima and minima temperatures are only approximate, being derived from but three to four years of signal service records:

Mean, maxima, and minima temperatures.

Locality.	Elevation above sea.	Latitude.	Longitude.	Years of record.	Mean.					Average maxima.					Average minima.				
					Spr.	Sum.	Aut.	Wr.	Yr.	Spr.	Sum.	Aut.	Wr.	Yr	Spr.	Sum.	Aut.	Wr.	Yr.
	Feet.	° ′	° ′		° ′	° ′	° ′	° ′	° ′	°	°	°	°	°	°	°	°	°	°
Fort Benton, Montana	2,730	47 50	110 39	1	44 70	71 15	48 72	25 14	47 43	.....	.....	.....	.....	.....	− 9	37	− 9	−28	−28
Fort Steele, Wyoming	6,500	41 45	107 10	2	40 99	66 36	45 88	22 48	43 93	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Bismarck, Dakota	1,650	46 47	100 46	3	38 17	66 76	39 04	7 97	38 21	86	100	85	51	100	−18	36	−12	−31	−31
Fort Sully, Dakota	.....	44 50	100 35	3	42 79	72 71	47 30	20 59	45 85	93	107	97	61	107	4	42	11	−12	−12
Yankton, Dakota	.....	42 54	97 21	4	45 02	71 20	46 18	17 14	44 88	88	107	97	61	107	− 8	42	11	−12	−12
Denver, Colorado	5,250	39 45	105 01	4	48 16	70 89	50 58	28 51	49 53	88	101	91	64	101	7	40	8	−15	−15
North Platte, Nebraska	2,800	41 08	100 46	3	47 07	71 05	48 74	23 50	47 81	80	101	90	66	101	0	37	0	−21	−21
Omaha, Nebraska	1,300	41 15	95 56	4	48 40	74 26	51 10	23 36	49 28	88	98	89	59	98	2	44	4	−15	−15
Fort Hays, Kansas	2,107	38 59	99 20	3	53 05	78 52	54 78	33 05	54 85	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fort Leavenworth, Kansas	890	39 21	94 54	40	53 60	75 24	54 35	29 35	53 10	90	100	93	66	100	9	47	10	− 9	− 9
Rolla, Missouri	950	37 58	91 44	4	52 93	74 29	54 24	33 78	53 81	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Saint Louis, Missouri	481	38 37	90 12	41	55 09	76 12	55 88	32 90	55 00	90	97	90	68	97	13	51	16	− 7	− 7
Montgomery, Alabama	162	32 23	86 18	1	66 72	.....	61 66	40 90	.....	95	101	93	77	101	33	62	33	10	10
New Haven, Connecticut	45	41 18	72 57	80	46 76	69 63	51 28	28 32	49 00	82	91	84	56	91	9	47	16	0	0

Winds.—The prevailing winds during the different seasons are shown by the Signal Service records to be as follows:

Prevailing winds.

Locality.	Years of record.	Spring.	Summer.	Autumn.	Winter.	Year.
Fort Benton, Montana	2	SW.	W.	SW.	SW.	SW.
Bismarck, Dakota	4	NW.	NW.	NW.	NW.	NW.
Fort Sully, Dakota	3	SE.	SE.	NW.	NW.	NW.
Yankton, Dakota	4	NW.	SE.	NW.	NW.	NW.
Denver, Colorado	4	S.	S.	S.	S.	S.
North Platte, Nebraska	4	SE.	SE.	NW.	NW.	NW.
Omaha, Nebraska	4	N.	S.	S.	NW.	S.
Leavenworth, Kansas	4	S.	S.	S.	S.	S.
Montgomery, Alabama	4	SE.	S.	NW.	N.	NW.
New Haven, Connecticut	4	NW.	S.	NW.	NW.	NW.

Humidity.—Regarding the humidity of the atmosphere, I have been able to find but one or two continuous records for particular stations, but from the Monthly Reviews in the Signal Service reports, I judge that the relative humidity for the year averages 0.40 to 0.50 in the upper basins of the Missouri and Platte, and 0.60 to 0.70 in the Lower Missouri valley, against 0.70 to 0.75 for the Gulf and New England states. For the year—July, 1877–June, 1878—the mean relative humidity at North Platte, Nebraska, was 0.616, and at Omaha, 0.696. In tables published by Professor F. H. Snow, of the Kansas State University, it appears that the mean relative humidity at Lawrence ranged, for different years, between 0.64 and 0.726, averaging for nine years, 0.672.

Rainfall.—There are not a great many points in the Missouri basin where records of rainfall have been kept for a long series of years, but its general distribution may be sufficiently well judged from the accompanying table, which embraces a number of localities, widely dispersed, where the most extended observations have been taken. The list is copied from the Smithsonian rain tables:

Rainfall.

Locality.	Elevation above sea.	Latitude.	Longitude.	Years of record.	Spring.	Summer.	Autumn.	Winter.	Year.
	Feet.	° ′	° ′		*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Fort Ellis, Montana	4,878	45 40	111 00	3	7.17	3.60	2.38	2.59	15.74
Fort Benton, Montana	2,730	47 50	110 40	7	5.34	4.48	1.65	1.79	13.26
Fort Bridger, Wyoming	6,656	41 20	110 23	13	2.99	2.05	1.68	1.71	8.43
Fort Steele, Wyoming	6,840	41 47	106 57	5	4.57	3.48	3.05	4.28	15.38
Fort Laramie, Wyoming	4,472	42 12	104 31	18	5.35	4.40	2.73	1.97	14.45
Fort Buford, Dakota	1,900	48 01	103 58	8	3.76	4.06	2.01	2.01	11.84
Fort Totten, Dakota	1,480	47 56	99 16	5	5.18	7.51	2.50	1.59	16.78
Fort Sully, Dakota	1,672	44 50	100 35	8	6.52	7.18	1.70	1.14	16.54
Yankton, Dakota	1,275	42 53	97 30	3	7.40	13.03	4.00	2.15	26.58
Denver, Colorado	5,250	39 45	105 00	5	5.02	3.69	3.16	1.90	13.77
North Platte, Nebraska	2,789	41 08	100 46	2	6.14	3.83	2.75	0.57	13.29
Fort Kearney, Nebraska	2,360	40 38	98 57	14	7.81	11.13	4.83	1.45	25.22
Omaha, Nebraska	1,300	41 15	95 56	10	7.68	15.00	7.15	3.01	32.84
Fort Hays, Kansas	2,107	38 50	99 20	7	6.93	6.23	5.77	3.77	22.70
Fort Leavenworth, Kansas	896	39 21	94 54	38	7.92	13.07	7.86	4.53	33.38
Fort Riley, Kansas	1,300	39 03	96 35	21	5.49	10.48	5.02	2.63	24.52
Lawrence, Kansas	850	38 58	95 12	9	8.83	12.59	7.38	4.30	33.10
Rolla, Missouri	950	37 58	91 44	9	11.67	11.13	8.04	6.66	37.50
Saint Louis, Missouri	481	38 37	90 12	40	11.71	13.01	8.58	7.39	40.69
Montgomery, Alabama	162	32 23	86 18	4	17.83	12.42	7.87	18.78	56.90
New Haven, Connecticut	45	41 18	72 57	27	11.24	12.11	11.19	10.90	45.44

SNOW.—I have but few data concerning the amount of snow falling on the Missouri basin. The records of Dr. A. S. Childs, of Plattsmouth, Nebraska, show an average of 23.5 inches per year for the fourteen years 1866–'79. Professor Snow gives the average at Lawrence, Kansas, for the five years 1868–'72, as 21.6 inches. Both these places are adjacent to the lower Missouri river. To the westward, on the plains, the snowfall is much lighter; the fall in the Rocky mountains is heavy, and the snow accumulates to great depths in the ravines.

EFFECTS OF RAINFALL, ETC., ON THE STREAMS.—In summing up the main points of the physical phenomena which have been mentioned, it is to be noticed:

(*a.*) That the range of temperature through the year is great, the mercury rising at most stations as high as 100°, and sinking as low as —10°, while in many localities the variation is still greater. The evaporation produced by the hot sun of summer, shining upon the almost unprotected surface of the prairies, is very large, and in a time of drought quickly brings down the volumes of the streams. Thus it is probable that such streams as the James river, of Dakota, and the Osage, of Missouri, during low stages lose as much by evaporation in their lower sluggish courses as they receive in those portions from their tributaries. Over almost the entire area drained by the Missouri the mean winter temperature is below 32°, so that whatever precipitation there is during that season must be mainly in the form of snow, and so remain upon the surface much of the time without greatly benefiting the streams.

(*b.*) For the upper basin, at least, the prevailing winds of the year, and especially of the winter season, are westerly, ranging from southwest to northwest. The winds blow steadily and quite briskly on the plains, there being comparatively few calm days, and coming dry from the Rocky mountains they assist largely in causing a rapid evaporation.

(*c.*) The relative humidity of the atmosphere is small, except in the lower Missouri valley, sinking frequently to 0.40, and at times to 0.30 or less, at Denver and Cheyenne.

(*d.*) The rainfall is small, and unevenly distributed through the year. For the localities represented in the preceding table the mean annual rainfall varies from 8.4 inches at Fort Bridger, Wyoming, to 40.7 at Saint Louis. It is less than 20 inches at most points west of the ninety-ninth meridian. Even more than the small annual rainfall is to be noticed the great contrast between the amounts falling in summer and winter. For points in Montana and Wyoming the precipitation seems to be greatest in spring and least in autumn; but for the Missouri basin, as a whole, the disproportion is greatest between summer and winter. The ratio which the rainfall of the former season bears to that of the latter is in different localities as follows:

Ratio of summer to winter rainfall.

Locality.	Ratio.	Locality.	Ratio.
Fort Ellis, Montana	1.4	North Platte, Nebraska	6.7
Fort Benton, Montana	2.5	Omaha, Nebraska	5.0
Fort Steele, Wyoming	0.8	Fort Hays, Kansas	1.7
Fort Laramie, Wyoming	2.2	Fort Leavenworth, Kansas	2.9
Fort Buford, Dakota	2.0	Saint Louis, Missouri	1.8
Yankton, Dakota	6.0	Montgomery, Alabama	0.7
Denver, Colorado	1.9	New Haven, Connecticut	1.1

The effect of the small precipitation of winter, combined with the low temperature of that season, is to bring most of the tributaries of the Missouri, excepting some farthest south, to their lowest stage in winter. On the other hand, we find them attaining their greatest volume in early and mid summer, a period when streams on the Atlantic coast are either in a falling stage or have reached the minimum.

DROUGHTS.—Concerning the prevalence and duration of droughts I can give no special information. They appear to be more severe, however, in the Missouri basin than on the Atlantic and Gulf slopes. This is indicated in the table below, where are given for a number of points in the above sections the ratios existing between the mean annual rainfall and the rainfall in an ordinarily dry year—not the dryest of a long term, but such as occurs once in five to eight years.

Ratio of rainfall in an ordinarily dry year to mean annual rainfall.

Locality.	Ratio.	Locality.	Ratio.
Missouri basin.		*Missouri basin*—Continued.	
Fort Benton, Montana	0.55	Saint Louis, Missouri	0.79
Fort Laramie, Wyoming	0.43	*Gulf slope.*	
Fort Buford, Dakota	0.60	Montgomery, Alabama	0.91
Yankton, Dakota	0.76	Atlanta, Georgia	0.94
Denver, Colorado	0.83	*North Atlantic slope.*	
Fort Kearney, Nebraska	0.77	Philadelphia, Pennsylvania	0.89
Omaha, Nebraska	0.65	New York city	0.91
Fort Hays, Kansas	0.70	New Haven, Connecticut	0.87
Fort Leavenworth, Kansas	0.76	Amherst, Massachusetts	0.90
Fort Scott, Kansas	0.71	Boston, Massachusetts	0.88
Fort Riley, Kansas	0.60	Brunswick, Maine	0.81
Lawrence, Kansas	0.92		
Rolla, Missouri	0.89		

INCREASING RAINFALL.—I have elsewhere spoken of the influence which the advancing cultivation of the prairies certainly has in the production of new springs and in maintaining the low-water flow of the streams. The same cause is also regarded by some as producing a better distributed and even increased annual rainfall. The subject is discussed in a very thorough manner by Professor Aughey in his work previously alluded to. The effect of cultivation is certainly very favorable, though there may be a question whether observations have been long enough continued to prove that the annual rainfall has been permanently increased.

II.—THE MISSOURI RIVER.

Although the Missouri river possesses no available water-power in that portion of its course which I visited, or, indeed, for a very long way above, yet it may be of interest, before describing the various tributaries, to give some account of the main stream, briefly setting forth its characteristic features.

The upper waters of this river were first explored in 1806, by Captains Lewis and Clarke, at a time when the highest settlement of whites on the stream was at La Charette creek, 68 miles from the Mississippi. Lewis and Clarke ascended the Missouri in small boats, noting down whatever appeared of interest, reconnoitering the tributaries for short distances above their mouths, and meeting with many strange adventures. They carried their explorations the length of the Missouri, and then continued up the Jefferson fork. On returning, Captain Clarke examined the Gallatin fork and a large part of the Yellowstone. For a succeeding period of nearly fifty years but little was added to the knowledge concerning the upper Missouri valley; but from the year 1853 to the present time numerous expeditions, reconnaissances, and surveys have been made by engineers and other officers of the United States Army, in the upper basin of the Missouri. Regarding the lower river, I think very little has been written in a connected and detailed manner. But within the past few years the efforts made for its improvement at various points, under the direction of Major Charles R. Suter, have led to its thorough and scientific study. A careful survey, to extend from the mouth to Fort Benton, is in progress.

The Missouri river proper is formed in southwestern Montana by the union of three forks, which, upon their discovery by Lewis and Clarke, were named by them Jefferson, Madison, and Gallatin, respectively. With reference to them the journal of Captain Lewis says:

On examining the two streams (Jefferson and Madison) it became difficult to decide which was the larger, or the real Missouri; they are each 90 yards wide, and so perfectly similar in character and appearance that they seem to have been formed in the same mold. We were therefore induced to discontinue the name of Missouri, and give to the southwest branch the name of Jefferson, in honor of the President of the United States, the projector of the enterprise; and called the middle branch Madison, after James Madison, Secretary of State. These two, as well as Gallatin river, run with great velocity, and throw out large bodies of water. Gallatin river is, however, the most rapid of the three, and, though not quite as deep, navigable for a considerable distance. Madison river, though much less rapid than the Gallatin, is somewhat more rapid than the Jefferson; the beds of all of them are formed of smooth pebbles and gravel, and the waters are perfectly transparent.

The Jefferson and Madison forks first come together, and within 2 miles are joined by the Gallatin.

The head of the Missouri, thus formed, lies about in latitude 45° 56′, and longitude 111° 32′. From this point the river takes a slightly northwesterly direction for about 80 miles by general course, and then runs northeast for an equal distance to Fort Benton. From the junction of the three forks at its head, the course of the Missouri lies for nearly a degree of latitude through mountain valleys and deep cañons; from these it finally issues through a gorge in a range of rocks, which Lewis and Clarke called the "gates of the Rocky mountains", and of which they gave this description:

A mile and a half beyond this creek the rocks approach the river on both sides, forming a most sublime and extraordinary spectacle. For 5¾ miles these rocks rise perpendicularly from the water's edge to the height of nearly 1,200 feet. They are composed of a black granite near their base, but from the lighter color above, and from the fragments, we suppose the upper part to be flint, of a yellowish-brown and cream color. Nothing can be imagined more tremendous than the frowning darkness of these rocks, which project over the river and menace us with destruction. The river, 150 yards in width, seems to have forced its channel down this solid mass; but so reluctantly has it given way, that during the whole distance the water is very deep, even at the edges, and for the first 3 miles there is not a spot, except one of a few yards, in which a man could stand between the water and the towering perpendicular of the mountains.

Thirty-five miles above Fort Benton the river pours over the Great falls, and from that point onward is a navigable stream. The following, concerning these falls, is from the report of Lieutenant Grover, United States Army:

There are five principal cascades. The first, about 3 miles below the mouth of the Sun river, falls about 25 feet. The second, nearly 3 miles below the first, is a small crooked cascade of 5 feet 11 inches pitch. Immediately below is the third. Here, between high banks, a ledge, nearly as straight as if formed by art, runs obliquely across the river, over which the water falls 42 feet in one continuous sheet, of 470 yards in width. At the foot of this cascade, so beautiful for its length and regularity, is a small island covered with willow, cottonwood, and wild cherry. Half a mile below this, again, is the fourth—a small, irregular fall of about 12 feet descent. There is a small knot of an island near the middle, and between that and the right bank of the river the ledge of the fall is very crooked, and the water reaches the basin below in two pitches. But between the island and the left bank there is simply a succession of rapids; the stream then hurries on, lashed and churned by numerous rapids, about 5 miles farther, where it precipitates itself over a precipice of 76 feet in height. This is the fifth and "Great fall" of the Missouri. The banks are high and abrupt on both sides, and above and below deep ravines, with bare, steep sides, extend out into the prairie from 1 to 2 miles. But opposite the fall, and on the north side, a narrow tongue of waving prairie runs near to the river, and breaks off in terraces to a small bottom below the cascade. The lower plain, embracing two or three acres, is a rounded point of land, which, with a rock-bound shoulder, half encircles the basin of the cascade, and for a short distance below confines the water-course to half its usual width. Near its head a broken and disconnected ledge of rocks rises some 30 feet or more above the water, but lower down there is some soil and a few scattered cottonwood, willow, and cherry trees.

For miles below its falls the course of the Missouri lies through a deep cañon; as far as the mouth of Maria's river its banks are 100 to 160 feet high, and it flows clear and transparent over a gravelly bed, with a current of about 2.7 miles an hour. From Fort Benton the general direction of the river is, for eight degrees of longitude, easterly along the forty-eighth parallel, from which it nowhere departs more than about 40 miles. In this distance the principal tributaries which it receives are, in order, the Musselshell, Milk, and Yellowstone. Below the mouth of Maria's river the banks of the Missouri are less abrupt, and rise by gentle slopes to the bluffs. From Fort Benton to Carroll, a distance of 167 miles, the river is rapid, with fixed channel and stable banks. The bed is largely composed of gravel, with numerous bowlders. The river now begins to change its character, and for 120 miles is intermediate between the rocky and rapid stream which it has previously been, and the shifting sand-bar river which it then becomes and continues to be for the remaining 215 miles to the mouth of the Yellowstone, and thence to the Mississippi. Its high-water width, which in the vicinity of Fort Benton is 500 to 1,000 feet, increases to 1,500 feet at the mouth of Milk river, and to 2,000 feet below the mouth of the Yellowstone.

The latter stream, almost the peer of the upper Missouri, deserves description. The upper Yellowstone has its source in northwestern Wyoming, a little below the parallel of 44°. It pursues a short course of 40 or 50 miles, and then enters the renowned Yellowstone lake, which may be considered the great source of the main river. The Yellowstone National Park occupies the northwestern corner of Wyoming territory. It is 65 miles long by 55 wide, and within its area, nearly half as large as the state of Massachusetts, embraces most wonderful scenery. Dr. Hayden says that the whole region was, in comparatively modern geological times, the scene of the most wonderful volcanic activity of any portion of this country. Here are seen great mountains, yawning cañons, and remarkable geysers and hot springs. A little southeast of the center of the park lies Yellowstone lake, about 20 miles long and 15 miles wide. Its shore line, which is rough and irregular, is said to measure 175 miles in length.

The lake lies at an altitude of 7,778 feet above the sea, and is, in places, nearly 300 feet deep. It is hemmed in on every side by lofty mountain ranges, and from the melting snows on their slopes its chief supply of water must come, since it receives no important tributaries.

In the early part of the day, when the air is still and the bright sunshine falls on its unruffled surface, its bright green color, shading to a delicate ultramarine, commands the admiration of every beholder. Later in the day, when the mountain winds come down from their icy heights, it puts on an aspect more in accordance with the fierce wilderness around it. Its shores are paved with volcanic rocks, sometimes in masses, sometimes broken and worn into pebbles of trachyte, obsidian, chalcedony, cornelians, agates, and bits of agatized wood; and again, ground to obsidian sand sprinkled with crystals of California diamonds.

Only 10 or 15 miles from the lake occur the Great Falls of the Yellowstone. In 1875 Captain William Ludlow explored this portion of the Yellowstone valley, and thus described the Upper fall:

Reserving the Lower fall, whose deep thunder we could now plainly hear, we descended toward the Upper, and after a short scramble over loose trachytic blocks, climbed out upon a point which, projecting into the cañon below the fall, furnished a fine view of it almost *en face*. The river makes a sharp bend to the eastward just above the fall, which in consequence fronts nearly at right angles to the general direction. From the sharp and narrow pinnacle on which we stood, or rather to which we clung, the cataract, some 150 feet distant, was exposed in its full height and beauty. It is a slanting one, having a base of, perhaps, one-half its altitude, which, as measured by a cord brought for the purpose, and marked in 10-foot lengths, is 110 feet. The water leaps down its rocky slope between black, shining walls of trachyte, and its pure green is broken into foam and spray from the very summit. From the foot the currents of air drove the clouds of vapor up the steep sides of the cañon, which were clothed in vegetation of the freshest and most brilliant hue, while a double rainbow illumined the surface of the stream below.

The Upper fall is only a quarter to a half mile from the Lower; of this Captain Ludlow says:

The view of the Grand cañon, from the point where we stood, is, perhaps, the finest piece of scenery in the world. I can conceive of no combination of pictorial splendors which could unite more potently the two requisites of majesty and beauty. Close at hand the river, narrowed in its bed to a width of some 70 feet, and with a depth of 4 to 5 feet, through the pure deep green of which the hardly wavering outlines of the brown bowlders beneath are distinctly visible, springs to the crest with an intensity of motion that makes its clear depths fairly seem to quiver. Just before making the plunge the stream is again contracted, and the waters are thrown in from both sides toward the center, so that two bold, rounded prominences or buttresses, as it were, are formed where green and white commingle. Lying prostrate and looking down into the depth, with the cold breath of the cañon fanning the face, one can see that these ribs continue downward, the whole mass of the fall gradually breaking into spray against the air, until lost in the vast cloud of vapor that hides its lowest third, and out of which comes up a mighty roar that shakes the hills and communicates a strange vibration to the nerves. The height of the fall, as ascertained by attaching a heavy weight to the measured cord and lowering it down, is 310 feet.

From the falls the river passes for 20 miles through the Grand cañon. This is impassable throughout, and at only a few points can the water's edge be reached; no sound comes up from its profound depth. Eighty miles, more or less, to the northward from Yellowstone lake the river issues from the Snow mountains, and then runs to the east and northeast till it joins the upper Missouri at Fort Buford, only a few miles on the Dakota side of the boundary between that and Montana territories. On emerging from the mountains the river is 600 feet wide and 6 feet deep. Thence to the mouth of Clarke's fork it is characterized by many islands and bold sweeping curves. Between Clarke's fork and the Big Horn it is 1,500 to 1,800 feet wide, free from rapids, and has a current of 3 to 4 miles an hour. The Big Horn river rises in the mountains some 30 miles south of the southeastern corner of Yellowstone National Park. For 100 miles by general course it flows in quite a direct course toward the southeast; but in the vicinity of latitude 43° north, and longitude 108° 30′ west, it turns abruptly northward, and though down to this point it has been known as Wind river, thence to the Yellowstone it is called the Big Horn. The length of the Big Horn, to the source of Wind river, is about 330 miles by general course, and it has a drainage area of about 22,360 square miles. From the Big Horn to Powder river the Yellowstone increases in width to from 2,400 to 2,700 feet, and becomes turbid like the Missouri. From Powder river to the Missouri the banks are low and caving, and the stream contains numerous sand-bars, densely-timbered islands, with some rapids and shoals.

The mouth of the Yellowstone is, according to Captain Raynolds, 1,894 miles above the mouth of the Missouri. Upon reaching the confluence of the Yellowstone and the upper Missouri, Lewis and Clarke measured the two streams with the following result:

Just above the confluence we measured the two rivers, and found the bed of the Missouri 520 yards wide, the water occupying only 330, and the channel deep, while the Yellowstone, including its sand-bar, occupied 858 yards, with 297 yards of water; the deepest part of the channel was 12 feet, but the river is now falling and seems to be nearly at its summer height.

From the point of junction, the Missouri follows a winding, but, on the whole, southeasterly course, passing over very nearly nine degrees of latitude, till it reaches the mouth of the Kansas river, in latitude 39° 6′; it then takes a more easterly direction across the state of Missouri, and empties into the Mississippi river 16 miles above Saint Louis, 189 above the mouth of the Ohio, and 2,824 miles below the point where it was formed by the union of Jefferson, Madison, and Gallatin forks. Below the Yellowstone the width continues quite uniform; from 2,000 feet it gradually increases to 3,000, which remains approximately its average width for the last 600 miles of its course. Six hundred and forty miles from the mouth it receives the Platte river, and again, 258 miles below, is joined by the Kansas.

The tributaries entering the Missouri below Fort Randall will hereafter be described in detail; the accompanying table gives the names of all the more important ones, in order from the headwaters of the main river, and their drainage areas:

Tributaries of the Missouri river.

Stream.	Drainage area.	Stream.	Drainage area.	Stream.	Drainage area.
	Sq. miles.		*Sq. miles.*		*Sq. miles.*
Jefferson fork	9,188	Powder river (to Yellowstone)	15,525	Little Sioux river	4,233
Madison fork	2,823	Little Missouri river	7,663	Platte river	90,467
Gallatin fork	1,728	Big Knife river	1,892	Nishnabatona river	3,100
Smith's river	2,604	Big Heart river	3,039	Nemaha river	1,924
Teton river, above Maria's	2,640	Cannon Ball river	4,244	Nodaway river	1,886
Maria's river, above Teton	7,556	Grand river	6,412	Platte river (of Missouri)	2,487
Judith river	2,524	Moreau river	4,633	Kansas river	59,757
Musselshell river	10,500	Big Cheyenne river	24,117	Grand river	7,932
Milk river	26,760	Bad river	3,059	Chariton river	2,900
Poplar river	3,508	White river	10,244	La Mine river	2,700
Big Muddy river	3,768	Niobrara river	13,200	Osage river	15,262
Yellowstone river	67,475	Dakota river	22,000	Gasconade river	3,667
Big Horn river (to Yellowstone)	22,360	Vermillion river	2,230		
Tongue river (to Yellowstone)	3,695	Big Sioux river	7,880		

Of the streams above the Niobrara I have but little information; of those below, only one, the Osage, is navigable at low water. Boats of 2-feet draught can ascend that river for about 50 miles. The Gasconade may be navigated at high water, and it is considered that both this river and the Kansas might be so improved as to be of value at low stages, though the expense involved would be considerable.

For information more directly concerning the physical features of the Missouri river I am indebted to the preliminary report by Major Charles R. Suter, Corps of Engineers, United States Army, who speaks as follows of the immediate valley:

> The main valley of the river consists of a great rock trough, from 1½ to 17 miles in width, cut down from the general level of the country to a depth considerably below the present level of the valley. The rocky banks form bluffs along the stream, and the bed is also of rock. This great trough seems to have been filled at one time with the Glacial Drift deposits, which also cover the adjacent country, and subsequently in part cleared out by the great river that probably occupied it in the early Post-Glacial times.
>
> The Drift deposits seem everywhere pretty well sorted out, bowlders are generally found next the rock, and deposits of varying degrees of coarseness above. The main feature is the great preponderance of extremely fine sand, which, with the addition of a very small amount of alumina, forms an extremely tenacious clay, locally known as "gumbo", and which is met with everywhere, and is formed in the bed of the stream wherever the current is unusually slackened. Large beds or pockets of very coarse gravel or pebbles are also met with in borings at different depths below the surface. They are usually water-worn fragments of quartz, mostly red and yellow jasper. The general absence of the large, high, and well-defined terraces which are usually found in valleys of this description, and the general prevalence in the surface soil of the very fine sand before alluded to, leads to the inference that the river, within comparatively recent times, has scoured over the greater part of the area embraced between the limiting bluffs, at least in the narrower portions of the valley.

From the report on founding piers for the Saint Joseph bridge, made by the engineer, Mr. W. S. Pope, it appears that the material through which the piers passed was, in general, fine sand or silt. Pockets of "gumbo" were met with, and snags and driftwood were of frequent occurrence. At a depth of 40 feet below the river-bed fragments of brick and pieces of coal were found. Usually the bed-rock was immediately overlaid by a deposit, 2 to 5 feet thick, of medium-sized bowlders and coarse sand. The bowlders were red and gray granite, schist, gneiss, conglomerate, trap, and quartz. The bed-rock was found to be a smooth, hard, whitish-gray limestone, overlaid with a broken shale 2 or 3 inches thick. While the Missouri river water is generally turbid, that found coursing along through the bottom deposit was pure and clear as spring water. Even when the ice was 2 feet thick on the surface, and the mercury was below zero, this water had a uniform temperature of 54° Fahrenheit.

The immediate bed of the river is of the most treacherous character. At the site of the Atchison bridge it was found to be composed of sand and gravel, and to be very shifting. The pivot pier was surrounded by sand to a depth of 35 feet, till in July, 1879, this deposit was entirely swept away, leaving the pier bare down to bed-rock. I was informed that, during the construction of the bridge, piles were sometimes driven one day in sand which was 25 feet deep, but which entirely disappeared within twenty-four hours.

Except in the mountain cañons the course of the Missouri lies through alluvial bottom-land of the most fertile character, and varying in width from 1½ miles near the mouth to 17 miles in the vicinity of Sioux City. In some places the bottom is apparently on a dead level; in others it has been cut up by high-water chutes, and frequently contains lakes which have resulted from cut-offs or changes in the course of the river; not uncommonly the immediate banks of the stream are found to be somewhat higher than the adjoining bottom, so that there is a downward slope from them in toward the bluffs. Through its alluvial flood-plain the river winds back and forth

from one bluff to the other, thus leaving tongues of land, which alternately reach out from one bluff to within a few thousand feet of the opposite. In the vicinity of Saint Joseph the Missouri is said to make eight complete crossings of the valley within a distance of 30 miles, measured in the direction of its general course.

The following table, furnished me by Major Suter, shows the width of the Missouri valley at various points, as measured between the bases of the bluffs:

Widths of the Missouri River valley.

Locality.	Average width.	Maximum width.	Minimum width.
	Miles.	*Miles.*	*Miles.*
Sioux City to a point 8 miles above Florence, Douglas county, Nebraska	10.54	17.00	7.00
Thence to a point 8 miles above Amazonia, Andrew county, Missouri	4.25	5.30	2.75
Thence to Kansas City	2.04	3.80	1.70
Thence to Glasgow	3.47	5.02	2.27
			1.80
Thence to mouth	2.00	3.10	1.50

From the mouth of the James to the "Big Bend", where the Missouri crosses the forty-eighth parallel, the average width of the bottoms is only 1 to 2 miles. Of this part of the river Humphreys and Abbot spoke as follows:

The Hupan-Kutey prairie, lying between this stream (the Big Sioux) and the Vermillion, is low and fertile, and is about the last of the continuous fertile country as you advance up the Missouri, which here comes from the west. Above this (to the upper big bend) the bottom-lands of the Missouri are sometimes 1 and 2 miles wide, and will give but precarious support to an agricultural people; it is doubtful whether even this can be said of the higher prairie lying back from the stream.

Above the "Big Bend" the valley widens somewhat, and up to a point 50 miles above the mouth of the Yellowstone has an average width of 3 to 6 miles.

The following table, giving the elevations and slope of the Missouri, is copied from Humphreys and Abbot's report:

Low-water slope of the Missouri river.

Locality.	Distance above the mouth.	Elevations above the Gulf.	Fall per mile.	Authority.
Big Horn branch.	*Miles.*	*Feet.*	*Feet.*	
Source (Wind river)	2,565	7,527	.....	Captain Raynolds.
Mouth of Popo Agie	2,450	5,347	18.90	Captain Raynolds.
Leaves Big Horn mountains	2,231	3,534	8.22	Captain Raynolds.
Mouth of Big Horn	2,159	2,831	0.78	Captain Raynolds.
Yellowstone branch.				
Source (lake)	2,439	(?) 6,500	.....	Captain Raynolds.
Leaves Snow mountains	2,345	4,705	19.10	Captain Raynolds.
Mouth of Big Horn	2,159	2,831	10.08	Captain Raynolds.
Mouth of Yellowstone	1,894	2,188	2.43	Captain Raynolds.
Upper Missouri branch.				
Source of Madison Fork	2,008	(?) 6,800	.....	Captain Raynolds.
Three forks of Missouri	2,824	4,319	29.52	Captain Raynolds.
Mouth of Sun river	2,680	3,573	5.54	Captain Raynolds.
Foot of falls	2,670	2,964	31.59	Captain Raynolds.
At Fort Benton	2,644	2,845	4.56	Captain Raynolds.
At Fort Union	1,894	2,194	0.88	Captain Raynolds.
At Fort Pierre	1,246	1,475	1.10	Lieutenant Warren.
At Sioux City	812	1,065	1.01	Railroad levels.
At Saint Joseph, Missouri	484	756	0.80	Railroad levels.
At mouth	.....	381	0.77	Railroad levels.
*Additional elevations.**				
Yellowstone at Glendive, Montana	.....	2,045	.....	Average low water, Northern Pacific railroad levels.
Little Missouri at Northern Pacific crossing	.....	2,245	.....	Average low water, Northern Pacific railroad levels.

* Not taken from Humphreys and Abbot's report.

The volume of the Missouri is subject to great variations, the ordinary high-water discharge at the mouth being about twenty-eight times that at low water. There are two causes of the freshets in this river—melting snow, and heavy summer rains. The amount of snow falling on the prairies is usually quite small, and in some

winters is scarcely worth mentioning, but amid the Rocky mountains snows begin early, continue late, and accumulate to great depth. As to the effect of this body of snow upon that portion of the Missouri above Milk river, Lieutenant Grover wrote:

> The fact of this part of the river lying near its sources in the Rocky mountains would naturally lead one to suppose that the changes in its volume of water from month to month would be nearly the same, for the same month, from year to year. This is found to be the case. As winter breaks up and warmer weather gradually comes on in the spring the ice becomes rotten, and the river is swollen by the melting of snow in the valley, and as early as the 1st of May the river is clear. Such is the great range of elevation, and, consequently, the great range of temperature, covered by this feeding reservoir of snow, that instead of melting in the short space of a month and swelling the river to a torrent, the process of melting commences with the valleys in the early spring, and goes on gradually to higher elevations as the season advances, constantly diminishing, of course, till August, when all that has a sensible effect upon the river is expended, when it commences falling more rapidly till the latter part of September.

The upper Missouri, the Yellowstone, the Big Cheyenne, and the Platte are the streams mainly affected by melting snow.

For a period of about two months, beginning in different years from the middle of May to the last of June, heavy local rains occur. The rainfall is sudden and violent, and frequently accompanied by thunder and lightning. During this period, the monthly rainfall is sometimes three or more times the average monthly rainfall for the year. From the widely extended, open, and, to a large extent, uncultivated, drainage-basins of the streams, floods of water pass down their channels and find their way into the Missouri, already raised by melting snows. At this season occurs what is termed the "big rise" or the "June rise".

Major Suter states, concerning the Missouri floods, in his preliminary report:

> The regular floods are two in number, and usually occur in April and in June. The first is extremely violent and of short duration, rarely lasting over a week or ten days; it seems to come largely from the upper river. The June rise, although generally higher, is of longer duration, being influenced by local rains and the general saturation of the soil. It is followed by a steady fall, which continues with considerable regularity till the freezing weather closes the small affluents as well as the upper river; then a sudden fall of 3 or 4 feet takes place, and the river reaches its winter level. There are occasional small rises of short duration besides those mentioned; one, especially, usually occurs late in the fall, but the two first mentioned, are, from all points of view, the most important.

Humphreys and Abbot give the range between high and low water in the Missouri as about 35 feet at the mouth, 20 feet at Saint Joseph, and only 6 feet at Fort Benton. The greatest recorded freshet in the lower river was that of 1844, although the rise of that year was somewhat exceeded temporarily at points on the upper river during the spring of 1881.

For the first 350 miles below the union of the Three Forks the Missouri is comparatively a clear stream, but in the vicinity of Carroll, Montana, approximately midway between the forks and the Yellowstone, its character gradually changes, and it becomes turbid. A similar change takes place in the Yellowstone below the mouth of the Big Horn, perhaps 250 miles above the Missouri. Although from the mountains the Missouri undoubtedly receives a large amount of sediment, especially that of the feldspathic and aluminous composition, yet it is mostly below the limits above given that it acquires its muddy appearance, which is due to the caving in of its banks.

To understand this action it is necessary to bear in mind the nature of the banks. An examination of the Saint Joseph river-front, in the vicinity of the bridge, by government engineers, showed the bank to be about 25 feet high at low water; it was composed of hard clay, not affected by the current. This material extended down 16 feet below low water, and at that depth was underlaid by 8 feet of quicksand; below this, clay, sand, gravel, and bowlders extended to bed-rock. This is but a single case, yet it probably illustrates the general character of the river banks throughout that part of the valley which we are considering. It is thought probable that in a rising stage the sediment carried by the Missouri is mainly brought in by the drainage of its tributaries. During that stage the banks become saturated with water, their cohesion is lessened, and at the same time they are being undermined by the washing out of the underlying strata of quicksand. As soon as the river begins to fall and uncover the banks they are filled with deep mud cracks, the sustaining pressure of the water is removed, and they are constantly caving in, a foot or two at a time, and sometimes in much greater masses. In this manner is supplied the larger part of the sediment belonging to a falling stage.

This action goes on with great rapidity, and during a single year the river may encroach 1,000 to 2,000 feet upon its banks. It is estimated that between Sioux City and the mouth of the Missouri the banks cave in, on the average, at the rate of 20,000,000 cubic feet per mile in the course of a year. A single illustration will show the speed with which erosion occasionally goes on. On July 8, 1877, a cut-off took place at Omaha, which resulted in throwing the river with great force against the Omaha bank. In his December report for that year Mr. Max Boehmer, United States assistant engineer, stated that in a short time, the exact length of which was not mentioned, the river had eaten into the bank a distance of 1,200 feet, till farther advance was stopped by throwing in sand-bags, stone, and brush, and by the construction of a revetment 2,000 feet long.

The Missouri now affords continuous navigation from its mouth to Fort Benton, in Montana territory, a distance of more than 2,600 miles; passing above Fort Benton we find it again navigable beyond the Great falls. But in speaking of the river as navigable below Fort Benton, it must not be understood that it is throughout this distance, or at all seasons of the year, favorable to such use, for that is not the case. In extremely low water there is not

much navigation on the lower river above Kansas City, less than 400 miles from the mouth, and even over that distance it is difficult. On the upper river considerable freighting is done to and from Fort Benton of government supplies, furs, hides, wool, and cattle.

On the lower river the principal hindrances to navigation are snags and shifting bars. The banks are generally timbered, and since they are so constantly caving in, especially during high water, they carry with them a great many large trees, which speedily sink and become imbedded in the river bottom, rendering safe progress for boats at night out of the question. During freshets the tributaries of the Missouri bring in a great deal of miscellaneous floating drift. I was informed that at the Kansas City bridge this sometimes lodges in masses against the piers, rapidly accumulates, and, if not broken up, is liable to dam up the river even more effectually than an ice-gorge. As we advance up the river, however, less and less timber appears upon its banks, and above the mouth of the James there are comparatively few snags.

The important cities which have sprung up on the banks of the Missouri, and the agricultural interests which have developed in its great valley, have alike demanded that some action should be taken toward the control of so dangerous a stream; and within the past few years considerable sums have been spent by the general government, mainly for the protection of threatened points. The work has been to some extent experimental, but very successful, and remarkable results have been brought about by the very simplest contrivances. The difficulties and great expense attending improvements carried on at a few remote points on the river, where the work is usually of very limited extent, and the advantages to accrue to the whole valley by its proper protection from the encroachments of the river, have led to the design of a general improvement of the Missouri below Sioux City. The points which are sought to be insured by this plan are, as stated by Major Suter:

> At any stage, equality of cross-section both in width and depth, uniformity of slope, and, in consequence, uniformity of velocity, while the channel at all stages shall be permanent in location.

Major Suter considers that from Sioux City to the mouth, a distance of about 800 miles, a uniform navigable depth of 12 feet at lowest stages can be guaranteed. It is estimated that, if this work be undertaken upon a sufficiently large scale, it may be completed for the above distance at a total expense of $8,000,000, or $10,000 per mile, the improvement to progress at the rate of about 100 miles a year.

As to the value of the Missouri river for water-power I can say but little. The upper portion of the stream, where it lies among the mountains, doubtless presents opportunities for realizing great power, though it is inaccessible, and no present demand exists for it. My visits to this river did not extend above Yankton, and it is evident that over the navigable portion of the Missouri the obtaining of useful power by any ordinary methods is not to be thought of. It has frequently been suggested that upon many of the rapid western rivers, such as the Missouri, Platte, Loup, and Elkhorn, paddle-wheels, supported upon barges moored in the current, might be used for power. I have not, however, met with any such device in operation, though there is a rumor of one having at some time been used in the Missouri at Sioux City. Weisbach gives the theoretical delivery of a paddle-wheel 15 feet high, with 8 floats, each 12 feet by 1 foot in the water, the latter having a velocity of 5 feet per second, to be 614 foot pounds per second, or a little more than one horse-power. The speed of the Missouri river current varies, in different localities and stages, from about 3 feet to 10 or 15 feet per second; but though it is possible to obtain small powers with some such contrivance as indicated above, still the results are too slight, and the practical disadvantages too great, to admit of their extended use.

Drainage areas of the Missouri river.

[Measured on General Land Office maps.]

Locality.	Square miles.	Locality.	Square miles.
Junction Three Forks of the Missouri river	13,730	Sioux City	312,183
Fort Benton	23,215	Above Platte river	322,500
Dauphin Rapids	30,499	Below Platte river	412,997
Below Milk river	86,201	Above Kansas river	420,800
Above Yellowstone river	98,010	Below Kansas river	486,650
Below Yellowstone river	166,385	Above Osage river	505,721
Bismarck (above Big Heart river)	188,084	Below Osage river	520,983
Fort Randall	203,651	Mouth of Missouri river	552,155

Summary of observations on discharge of the Missouri river at Saint Charles, for the year 1879.

[Measurements made under the direction of Major Charles R. Suter.]

Month.	Total discharge in cubic feet.	Average daily discharge in cubic feet.	Average discharge in cubic feet per second.	Average discharge in cubic feet per second per square mile of drainage area.*
January	91,787,040,000	2,960,872,258	34,269	0.06503
February	86,550,299,000	3,091,082,129	35,776	0.06789
March	109,479,080,400	3,531,002,787	40,875	0.07756
April	278,897,942,400	9,294,598,080	107,576	0.20413
May	206,505,036,000	6,661,481,807	77,100	0.14630
June	413,716,291,200	13,790,543,040	159,613	0.30287
July	481,738,838,400	15,530,962,529	179,801	0.34120
August	225,540,259,000	7,275,085,793	84,209	0.15979
September	100,480,694,400	3,349,356,480	38,766	0.07356
October	80,238,343,200	2,588,349,781	29,958	0.05685
November	133,090,807,200	4,456,362,240	51,578	0.09787
December	126,571,248,000	4,082,943,484	47,256	0.08967
Total	2,335,143,946,400	6,397,654,648	74,047	0.14051

* Drainage area assumed at 527,000 square miles.

III.—TRIBUTARIES ON THE EAST SIDE OF THE MISSOURI RIVER, BELOW YANKTON.

In describing those rivers which are tributary to the Missouri on the east, I shall consider the more important ones in order, beginning with the Dakota and ending with the Chariton. Above the former stream the country is but little developed at present, while below the Chariton no accessions of any consequence are received from the left.

THE DAKOTA RIVER.

Taking its rise in Gingras county, in northern Dakota, this river flows over a long and crooked course having a general bearing to the south, and finally reaches the Missouri about 9 miles east of Yankton. It is said to have been called *Rivière Jacques* by early French traders, a name which became, in English, James river, and by which it is still commonly known, although its name has been declared by law to be the Dakota river. Its source is distant but a few miles from the headwaters of the Cheyenne, which empties into the Red River of the North. Its basin stretches thence to the southward through five degrees of latitude, and is 340 miles long, with a width varying from 60 to 90 miles. The area included within its water-shed lines I estimate as about 22,000 square miles; but the topography of this region is so little known, and so slightly represented on maps, that these figures cannot be considered very accurate. Following the general course of the river, and neglecting the lesser curves, its length is 415 miles; but if all the curves were taken into account, by accurate meandering, it would doubtless appear two or three times as long. In Dakota it is popularly regarded as the longest river in the world that has no natural capabilities for navigation.

The greater part of this river is so difficult of access, that I have been able to obtain but little information in detail concerning either its own features or those of the valley and surrounding country. This region was evidently once covered by glaciers, and the line of a terminal moraine, passing down between the Missouri and Dakota rivers, crosses the lower course of the latter. Deposits of drift material are displayed along the river, and appear also upon the face of the surrounding country, though not to such an extent as to interfere with its cultivation. A great many small lakes are to be seen, which were probably left when the glaciers had receded; some of these drain into the Dakota river, but most are apparently isolated. Within 30 miles of the river there are numerous little creeks which find their way into it, but they are of no consequence, and during fall and winter many of them run entirely dry.

The valley of the main stream has been discovered to be of great fertility, well adapted to the production of wheat and corn, and within a year or two has attracted a considerable immigration. Still this section is but sparsely settled, and the combined population of all the counties directly bordering the river is only about 23,000; and 80 per cent. of this number is confined to the six lower counties. Mitchell, on the lower river, and Jamestown, on the upper course, are two of the most important places. Lines of railroad already cross the stream at various points, and are pushing on to the westward. A north-and-south line is being built along the valley, and from Jamestown the Northern Pacific Railroad Company is extending a branch to the northwest, toward Mouse river.

Although the Dakota river is not naturally navigable, it is considered by some that slack-water navigation is practicable, especially toward the mouth. In consequence of a dam at Columbia, slack water is caused for a long distance above, and small boats are enabled to use that portion of the river, during a part of the year, as far north as Grand Rapids, some 70 miles by general course above Columbia. In 1874 an examination of the river was made by a government engineer. (*a*) The stream was found to be so tortuous, and to carry so small a volume of water, that improvement of the natural channel by ordinary methods was not thought practicable; it also seemed doubtful whether, by damming the outlet of lake Tchanchicaha, sufficient water could be stored even to supply a canal.

The immediate course of the river lies through bottom-land, which is sometimes gently rolling and gravelly, and again flat and marshy. From the bottom-land there is a gradual rise to the bluffs, which are low; and beyond these stretches the open prairie. In the vicinity of Jamestown, and for 40 miles below, there is a slight fringe of timber along the stream; but over the greater part of the country drained by the Dakota none of any importance appears. Along the course of the stream there are several lakes, which are merely widenings-out of the channel; two of these occur 25 miles north of Jamestown and have received the names of Arrowwood and Jim lakes. Each is about 6 miles long, half a mile wide, and with banks 20 to 40 feet high. They might be of some value for storage, but it is said that if they were to be raised by a dam the structure would need to be 1,200 or 1,300 feet long.

The Northern Pacific railroad crosses the river at Jamestown, county-seat of Stutsman county. A small power is used at this point by a flouring-mill; the dam is of crib-work, with brush and stone filling, and gives a head of 9 feet. In summer the river is 25 or 30 feet wide here, and the privilege is considered good for 40 horse-power; but in winter the width is only 10 or 15 feet and the supply of water is so small that the water-power is worthless. The banks are about 10 or 15 feet high above low-water, and are the same at Grand Rapids. Between Jamestown and the latter locality the river has a fall of 100 feet or more, with no sites improved, though it was reported that work on one dam had been begun. From the government engineer's report, previously alluded to, it appears that from a point distant 3 miles below Jamestown a chain of rapids extends for 9 miles, with a fall of 54 feet. From this section down to the vicinity of Grand Rapids there are numerous riffles; some of these are 2 miles or more in length, and one has, for 4 miles, a fall of 12 feet per mile. From Jamestown to Grand Rapids the river-bed is composed of sand, gravel, and bowlders, and the banks range in height from 10 to 18 feet. The volume is small at low-water, but flouring- and grist-mills of moderate size could probably run during the greater part of the year.

At Grand Rapids a dam 9 feet high has been built of brush and gravel in alternate layers; but the power is not yet in use. Below Grand Rapids the river is very sluggish, and has but a slight descent. General W. H. H. Beadle, of Yankton, says of the portion lying above Columbia:

> I have surveyed public lands at various points for 80 miles below Jamestown, and have traveled along the Dakota (James) river from Yankton to Jamestown several times in 1873 and since. In my surveys I have had occasion to cross the river by wading it in probably thirty places between Grand Rapids and Columbia. Speaking of that region especially, from a short distance below Grand Rapids to Columbia—some 60 miles by road and 120 by river—there is practically no fall to the river. I have measured the width of water in twenty or thirty places, and it is from 2½ to 4½ chains wide, or from 160 to 300 feet—nowhere narrower than 150 feet, I believe. Its depth is very uniform, about 3½ feet in July, August, and September, the dry season. In places it is 5 or 6 feet deep.
>
> The banks are usually the black loam and clay of the bottom-lands, though in places they are higher and more solid and dry. Heavy grass grows on them and very often down into the water from 5 to 15 feet. This part of the river and generally near the banks is muddy, a man sinking easily 8 to 12 inches in it, but in the middle of the stream, for a width of 60 to 100 feet, the bottom is firm and often hard, apparently sandy, on the surface at least. A dam at Columbia would back the water nearly to Grand Rapids; a dam elevated 12 feet would back it above Grand Rapids. That rise would fill the banks in most places and overflow some low ground, not so valuable for any other purpose. The surface of water obtained by a dam 12 or 15 feet high at Columbia would reach, including the so-called lake above Columbia, an area of 15 or more square miles, and would afford a vast storage for water to be used at the dam and at numerous mill-sites 200 miles below to the Missouri river.

The river continues sluggish throughout the remainder of its course. The bed is generally muddy, but there is an outcrop of sandstone at Rockport, and it is reported that both sandstone and limestone appear 20 miles above. No power is used except by a few flouring- and grist-mills below Mitchell. Between that point and the mouth of the river a total fall of 38½ feet is returned as thus employed, probably leaving but little of the descent of the stream unimproved. The dams average perhaps 100 feet in length by 8 in height, and are of varied construction; in some cases framed, while in others they are rudely built of stone and backed with earth.

No continuous line of levels has been run along the course of the Dakota river. Railroad surveys show the river surface at the Northern Pacific crossing to be 1,385 feet above the sea; and at the Chicago and Northwestern crossing, in Beadle county, 1,228 feet above the sea. By map measurement the intervening distance is 252 miles, in which there is thus a descent of 157 feet, or an average of 0.62 foot per mile.

The rainfall over the basin of this river may be taken as approximately 6 inches in spring, 10 in summer, 3 in autumn, and 2 in winter, making a total of 21 inches for the year. No measurements have been made of the volume of the stream, and it cannot be estimated with much accuracy. For low stages, however, the rate of discharge probably lies between 0.01 and 0.02 cubic foot per second per square mile of drainage area.

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a See *Report Chief of Engineers*, 1874.

Estimated volume and horse-power of the Dakota river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.			LOW WATER, AVERAGE YEAR.			AVAILABLE 8 TO 10 MONTHS IN AVERAGE YEAR.		
		Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.									
Jamestown	3,500	0.005	18	20	0.009	30	34	0.023	80	90
Grand Rapids	5,500	0.005	28	32	0.013	70	80	0.024	130	150
Columbia	10,000	0.007	70	80	0.015	150	170	0.025	250	280
Rockport	20,500	0.008	160	180	0.018	370	420	0.026	530	600
Mouth of river	22,000	0.008	180	430	0.020	440	500	0.028	620	700

THE VERMILION RIVER.

Two small streams, the East and West forks, unite in Turner county, Dakota, to form the main river, which then flows southerly to the Missouri. From the junction of the two forks to the mouth the distance by general course is about 45 miles. The drainage basin comprises an area of 2,230 square miles. Its surface is rolling, destitute of timber, and fertile from the bottoms of the valleys to the tops of the hills. Its value for agriculture has attracted a rapid settlement by people of various nationalities, including many Russian Mennonites.

The East and West forks are not more than 10 or 15 feet wide in an ordinary stage, and the average width of the main stream is probably not greater that 30 feet. It has very little value for power; there are a few flouring- and grist-mills, which obtain power for two or three runs of stone, but they are short of water part of the year, and are obliged to use steam in some cases. The volume of the stream is derived, not from springs, but from surface drainage, and hence, during the fall and winter, when the rainfall is light, there is but little water flowing—in fact, the East and West forks often dry up entirely, or become a mere chain of stagnant pools.

THE BIG SIOUX RIVER.

So far as concerns value for water-power, the Big Sioux is probably the most important tributary of the Missouri on the east; mainly because of its size, its rate of descent, and the large fall over rock ledges occurring at Sioux Falls. It rises 20 to 25 miles west of Big Stone lake, in the southern part of the Sisseton and Wahpeton Indian reservation, in Dakota. It runs southerly, nowhere more than 35 miles west of the Minnesota boundary, and reaches the Missouri river a short distance above Sioux City. The latter part of its course forms the division between Dakota and Iowa. The length by general course is about 210 miles, but the river is very winding and the true length is much greater. There is an exceptionally long bend at Sioux Falls, where, between points distant but 2½ miles in a straight line, the intervening distance by water is claimed to be 17 miles.

The area drained by the Big Sioux includes about 7,880 square miles. The surface is a rolling prairie, fertile, but almost entirely without timber. Scarcity of fuel is, indeed, an important defect in this section, and the settlers are sometimes compelled to resort to burning hay, sunflower stalks, and corn, as substitutes for coal and wood. The basin of the Sioux contains a great many Drift lakes, similar to those found in such large numbers in Minnesota; they are not seen below Sioux Falls, but above that locality are very numerous. Kampeska, Poinsett, and the Chain lakes are some of the most important ones. The latter are said to cover an area of 15 square miles, and Kampeska and Poinsett are still larger. The Drift lakes are usually of fair depth, and though in most cases they have no apparent inlet or outlet, still their waters do not become stagnant. They undoubtedly assist in maintaining the low-water volume of neighboring streams, by percolation through the ground. None of the lakes which drain into the Sioux are dammed, but the opinion was expressed by a surveyor well acquainted with the country, that all the larger ones might be thus improved, at a total expense of not more than $50,000, and rendered valuable as storage reservoirs. The evaporation from their surfaces must be very great. They lie in an open country, elevated 1,500 feet or more above the sea, and the brisk, dry winds, which are constantly sweeping over their surfaces, make heavy drafts on their volume.

The agricultural value of this region has invited a rapid settlement, and, according to the statistics of Mr. Henry Gannett, the population of the Big Sioux basin has increased from 6,173 in 1870, to 61,019 in 1880. This development has been fostered and hastened by constant railroad extension. At numerous points, well scattered along the whole course of the river, it is crossed by east-and-west lines, and a division of the Chicago, Milwaukee and Saint Paul road follows up the valley. The immediate valley of the stream is usually 1 mile to 3 miles wide, and above Sioux Falls is probably composed of modified Drift. In the lower course it is alluvial, and presents a wide, flat surface, bounded by distinctly defined bluffs. At Sioux Falls there is an interesting exposure of red Sioux

quartzite, which is said to appear at intervals to the eastward in Minnesota, and westward to the Missouri river. Possibly it was this, and not sandstone, which was reported to me as being found at Rockport, and points above on the Dakota river. There are also occasional outcropping ledges of rock at points on the river above Sioux Falls.

In Minnehaha county the Sioux is 100 to 150 feet wide, rapid and shallow, inclosed by banks 10 to 20 feet in height. In its lower course the average width is perhaps 200 feet, while the current is generally sluggish, varied now and then by riffles. The banks are of loam, except where, as at Sioux Falls and above, rock appears. The stream is well sustained by springs, and has a steady flow from month to month. It is not much affected by ordinary storms, and has only once overflowed its banks extensively in twelve years.

Elevations on Big Sioux river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Feet per mile.*
Watertown†	1,760	113	44	2.57
Near Brookings†	1,596			
Mouth of river‡	1,070	526	177	2.97

* Map measurement. † Water surface at Chicago and Northwestern crossing. ‡ Estimated.

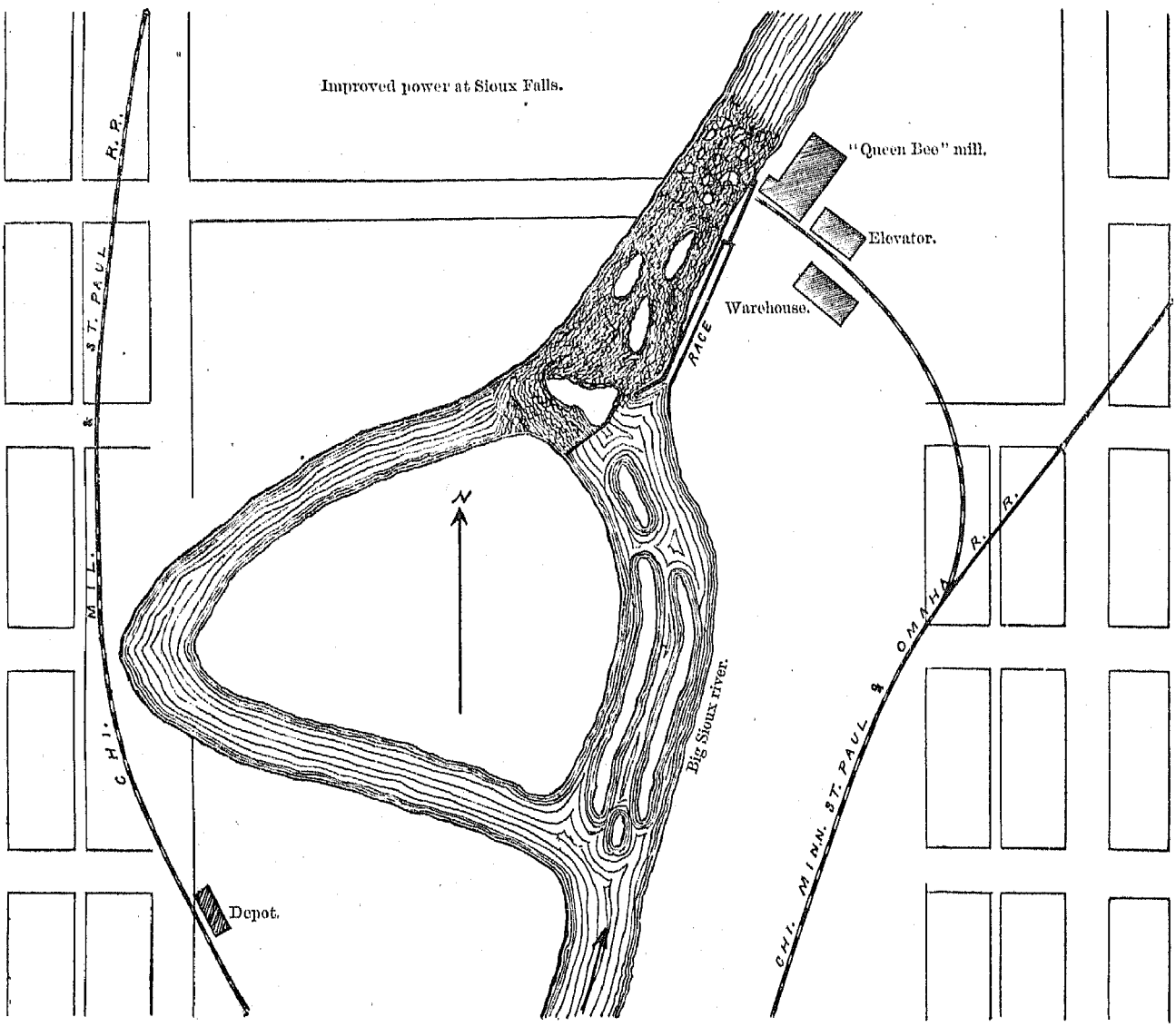
Below Sioux Falls power is employed by a number of small flouring- and grist-mills, carrying from two to four runs each, and having a large surplus of water. The dams are 150 to 300 feet long, about 8 feet high, and are said to be usually built of logs. There are doubtless available sites on this part of the river still unimproved.

The most important power on the river is that at Sioux Falls, which probably has no equal within 200 miles in natural value and thoroughness of development. The city where this power is located was but a few years ago a mere Indian trading-post. It is situated on a bend in the river in the southeastern part of Minnehaha county, and has good railroad connections in all directions. The river here descends 60 or 70 feet within a short distance. The falls are caused by outcroppings of red quartzite, ledges of which cross the stream. The appearance of such a mass of rock in a section where extensive exposures are rare, and the natural beauty of the falls, combine to render the place of note far and wide. The rock is so hard that it will scratch glass, and is susceptible of a beautiful polish; it is difficult to work, but still has been used successfully in the construction of race walls and a large mill, and a quarry has been opened near the river, where the stone is obtained in slabs of convenient shape, and large enough, if desired, to weigh several tons each. Where the Sioux quartzite is exposed, at the falls, its surface has been weathered till quite smooth, and it is full of vertical fissures running at right angles to each other. The ledges form a kind of natural dam, over which the river rushes in a succession of beautiful cascades.

At the time this power was visited its improvement was in a very advanced stage, and was expected to be completed during the year 1881. The privilege is owned by the Sioux Falls Water-Power Company, having a paid-in capital stock of $450,000. The work of improvement has been done in the most substantial manner. It has not been confined to the mere erection of a dam and provision of water and building-sites, but the design has been to provide everything—water, mill, and machinery—ready for use. To this end there has been built what is called the "Queen Bee" mill, at a cost of $200,000; it is 100 feet long, 80 feet wide, and seven stories high. It is strongly built, with thick walls of the hard quartzite already described; within are found the most recent improved kinds of machinery for the manufacture of flour, and all conveniences.

The present capacity of the mill is 600 barrels of flour a day, and it is claimed to have a possible capacity, when fully employed, of 1,200 barrels a day. At the time of my visit the rates to be charged for power had not been fixed upon. Adjoining the Queen Bee mill is a grain elevator with a capacity of 125,000 bushels. The shipping facilities are good, and spur tracks run directly to the mill.

As already stated, the rock ledges form a very good natural dam, and the only artificial addition necessary is a low framed structure, 70 feet long and 4 feet high. The descent of the river is so rapid that the pond will be small, covering but a few acres. From the head of the falls a race has been blasted out for about 200 feet, and flanked by heavy masonry walls. The race is 25 feet wide and 12 feet deep; at its extremity there is a bulkhead of masonry, pierced by two circular openings; from one of these a tubular iron flume, 7 feet in diameter, and made of No. 4 iron, weighing 683 pounds to the sheet, conveys water to the wheel-pit. The second opening in the bulkhead is now closed by a gate, but will be used in time for the entrance to another tube, to carry water for additional power. The head of water on the wheels is 56 feet 4 inches, and the privilege is claimed to be good for 1,240 horse-power (theoretical) in the ordinary stage of river, and for 2,000 horse-power many months in the year; about 300 horse-power will be used in the Queen Bee mill. The water-power company owns an additional fall of 14 feet below this one, which will not be used at present.



IMPROVED POWER AT SIOUX FALLS.

This section of Dakota is well suited to sheep raising, and though the power I have described has been developed mainly with a view to the manufacture of flour, it is hoped that there may be attracted to it establishments to engage in woolen and paper manufacturing. In the absence of any records of gaugings, I estimate the power available at Sioux Falls as follows:

Estimate of power at Sioux Falls.

Drainage area, 4,370 square miles.	Low water, ordinarily dry year.	Low water, average year.	Available ten months in average year.
Volume, cubic feet per second	70.0	110.0	180.0
Theoretical horse-power:			
1 foot head	8.0	12.5	20.4
10 feet head	80.0	125.0	204.0
56 feet head	450.0	700.0	1,140.0
70 feet head	560.0	875.0	1,430.0

A short distance above the water-power company's privilege is another, occupied by the Cascade flouring-mill. Four runs of stone are carried, the water-wheel being rated at 75 horse-power, and working under a head of 8 feet. There is water enough to run the mill at full capacity ten months in the year, and nearly at full capacity the

remainder of the time. The dam was built in 1877, and cost $4,500. It is a stone structure, 190 feet long and 5 feet high, and sets the river back for about 3 miles. There is another flouring-mill below the falls, but I have no particulars concerning the power.

Ascending the river, the next improved power above Sioux Falls is at Dell Rapids, 17 miles north, where there is a four-run flouring-mill, using about 40 horse-power, with 17 feet fall; the privilege is owned by Mr. William Van Epps, of Sioux Falls. A stone dam was built in 1878, at a cost of $2,000; it is 40 feet long, 14 feet high, and has a width of 14 feet at the base, decreasing to 7 feet at the top. Mr. Van Epps considers his privilege good for ten runs of stone ten months in the year.

The only mill above Dell Rapids, of which I could learn positively, was one at Flandreau, in Moody county; three runs of stone are carried there by a flouring-mill using 10 feet fall. The dam is mainly of brush and gravel, 68 feet long and 10 feet high; it is supplemented by an embankment 300 feet long and perhaps 5 feet high, the cost of the whole structure having been approximately $2,500. The river is set back so as to form a pond of about 100 acres, averaging 4 or 5 feet in depth.

There were reported to be one or two small grist-mills below Flandreau, either already built or in process of construction, but I learned no details regarding them. Only a small portion of the fall in this upper part of the river is yet improved. The locations of all the unoccupied sites can not be given, but I was informed by Mr. R. F. Pettigrew, of Sioux Falls, a gentleman who has surveyed along this section of the river, that there is a good unimproved privilege 2 miles above Flandreau, with 9 feet fall; four or five privileges, with about 10 feet fall each, between Egan (below Flandreau) and Dell Rapids; two near Sioux Falls, with stone ledges; and four or five below Sioux Falls, between that point and Canton. Generally speaking, a power may be developed every 3 or 4 miles, with an available head of ten feet. Above Flandreau there is hardly enough water for good powers, but by raising Kampeska lake, this section would be made valuable. That lake has an area of 28 square miles; it has a gravelly bed and is fed by springs. During high water, the Big Sioux sends part of its volume into the lake through a side channel, but as the river goes down it receives drainage from the lake through the same channel.

The rainfall on the basin of the Big Sioux river is about 7 inches in spring, 12 in summer, 4 in autumn, 2 in winter, and 25 for the year. I can learn of no gauging having been made on this stream, and therefore base my estimate of its volume upon a comparison with the Minnesota river. The country drained by the latter river above Judson is similar to that drained by the Big Sioux; the rainfall during the different seasons is also substantially the same over both districts. In the report by General G. K. Warren, Corps of Engineers, on the Minnesota river, (*a*) its low-water volume at different points is given as in the following table:

Low-water volumes of Minnesota river.

[Lowest observed, but not necessarily the lowest that there have been.]

Locality.	Drainage area.	Volume, cubic feet per second.	Cubic feet per second per square mile.
	Square miles.		
Foot of Big Stone lake	920	11	0.012
Above Pomme de Terre creek	2,620	42	0.016
Above Redwood river	8,540	217	0.025
Fort Ridgeley	9,850	253	0.026
Above Big Cottonwood river	10,190	307	0.030
Judson	11,940	397	0.033
Belle Plaine	16,380	1,575	0.096
Above Little Rapids	16,660	1,924	0.115
Mouth of river	17,290	* 1,155	0.067

* Observed November 25, 1867.

The basin of the Minnesota is a prairie region above Judson, but below that point soon becomes thickly wooded.

For the Big Sioux river I assume the rates of discharge to be:

(1) Low water of an ordinarily dry year, 0.016 to 0.018 cubic foot per second per square mile of drainage area.

(2) Low water of an average year, 0.025 to 0.027 cubic foot per second per square mile.

(3) Available ten months in an average year, 0.040 to 0.043 cubic foot per second per square mile.

a See Appendix J., *Report Chief of Engineers*, 1875, page 53.

The resulting volume and horse-power are as shown below:

Estimated volume and horse-power: Big Sioux river.

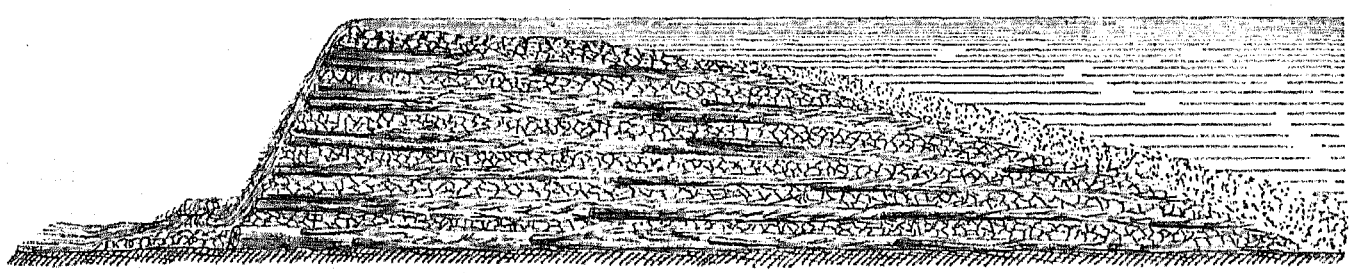
Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.			LOW WATER, AVERAGE YEAR.			AVAILABLE 10 MONTHS IN AVERAGE YEAR.		
		Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.									
Flandreau	3,270	0.016	50	60	0.025	80	90	0.040	130	150
Dell Rapids	3,560	0.016	60	70	0.025	90	100	0.042	150	170
Sioux Falls	4,370	0.017	70	80	0.026	110	125	0.042	180	200
Eden	5,300	0.018	90	100	0.026	140	160	0.043	230	260
Mouth of river	7,880	0.018	140	160	0.027	210	240	0.043	340	390

Of the tributaries of the Big Sioux, Split Rock creek, which comes in to the east of Sioux Falls, is used by a small grist-mill at Palisade, but carries scarcely enough water for that, and is of no importance.

ROCK RIVER.

This is the largest tributary. It rises in Pipe Stone county, in southwestern Minnesota, and, flowing southerly, runs across the northwest corner of Iowa and empties into the Big Sioux 45 miles, by general course, above its mouth. The bed and banks are generally sand and gravel, and display no ledges. The banks are low, and on one side or the other are frequently not more that 3 feet above low water. The stream is fairly steady; it rises, however, with the June rains and overflows its banks half a mile in width on each side. It commonly runs an average of 30 to 50 feet wide and 2 to 4 feet deep, with a moderate current.

Power is said to be used by flouring-mills at the following points: Luverne, one mill of two runs; Ash creek, one mill of two runs; Rock Rapids, two mills, each three runs; Rock valley (near the mouth), one mill of four or five runs. The dams are estimated to average 50 to 75 feet in length, 7 to 8 feet in height, and are in some cases constructed of brush. In building the latter, the bed of the stream is first covered with logs or trees having their branches on, the buts down-stream; upon these are added successive layers of brush and stone, and the interstices are filled with earth and manure. This style of dam is claimed to be durable and reasonably tight. The Luverne



SKETCH SHOWING CROSS-SECTION OF BRUSH DAM.

mill has a brush dam 45 feet long and 4½ feet high, which was built in 1878, at a cost of $200. The pond extends a mile and a half up the river. The mill is able to run at full capacity at least ten months in the year.

Estimated volume and horse-power: Rock river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.			LOW WATER, AVERAGE YEAR.			AVAILABLE 10 MONTHS IN AVERAGE YEAR.		
		Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.									
Luverne	450	0.010	5	6	0.045	20	23	0.065	30	34
Rock Rapids	800	0.010	8	9	0.045	35	40	0.065	50	57
Mouth of river	1,060	0.015	25	29	0.045	75	85	0.065	110	125

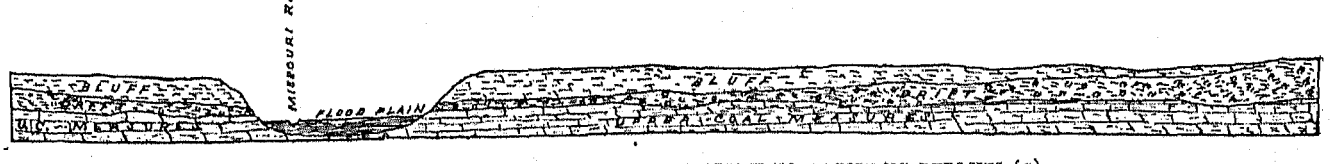
Summary of power used on rivers of southeastern Dakota.

Stream.	Tributary to what.	State or territory.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Dakota	Missouri	Dakota	Yankton	Flour and grist	1	6½	36
Do	do	do	Hutchinson	do	1	8	42
Do	do	do	Armstrong	do	2	14	60
Do	do	do	Hanson	do	1	10	50
Do	do	do	Stutsman	do	1	9	40
Total					6	47½	228
Vermillion	do	do	Clay	do	2	15	81
Do	do	do	Turner	do	3	20	52
Total					5	35	133
Big Sioux	do	Iowa	Plymouth	do	1	5	40
Do	do	do	Lyon	do	1	10	60
Do	do	Dakota	Union	do	2	12	57
Do	do	do	Lincoln	do	2	10	70
Do	do	do	Minnehaha	do	*4	42½	178
Do	do	do	Moody	do	1	10	45
Total					11	95½	450
Split Rock	Big Sioux	do	Minnehaha	do	1	23	50
Rock	do	Iowa	Sioux	do	1	10	50
Do	do	do	Lyon	do	1	14	60
Do	do	Minnesota	Rock	do	2	17	63
Total					4	41	173

*Not including power of Sioux Falls Water-Power Company, not yet in use.

TRIBUTARIES OF THE MISSOURI RIVER IN WESTERN IOWA.

In this class are comprised those rivers which the Missouri receives from the east, below the Big Sioux, extending to and including the Nishnabatona. The other principal streams thus embraced are the Floyd, Little Sioux, Soldier, and Boyer. The feature to which I wish especially to call attention is the geology of the region drained by these rivers. It is underlaid directly by only two formations—the Cretaceous and the Upper Coal Measures. Near the mouth of the Floyd, on the lower Boyer, and at points on the East and West Nishnabatona, their strata are slightly exposed, but in general they are concealed beneath the overlying Drift and Loess. The Drift is 150 to 200 feet thick along the ridge which divides the drainage basins of these streams from the basin of the Des Moines, and maintains a good thickness in northwestern Iowa. The Loess is thinnest on this ridge, but grows deeper as the Missouri river is approached, and in Fremont county, in southwestern Iowa, attains a depth of 200 feet.



SKETCH SHOWING RELATION OF RIVER VALLEY TO ADJOINING DEPOSITS (*a*).

The Loess, or Bluff deposit, as it is also called, is very pervious to water, and would probably have the same effect as sand in maintaining a uniform and large flow in the streams, if these had cut their way sufficiently deep to reach an impervious stratum which should shed the water into them. But in most cases they have not done this, and, consequently, much of the rainfall probably sinks to greater depths, runs along upon and through the underlying formations, and is lost to these streams. Dr. Charles A. White says of this deposit (*a*):

> Water passes through the material of the Bluff deposit as effectually as through ordinary sand, but not so quickly. That it is very pervious to water may be readily seen by observing the line of springs that issue at its base near the foot of the bluffs, and nowhere above that line. That it is so pervious also appears from the fact that wells dug in it, so far as has yet been ascertained, have never afforded a supply of water until the base, or very near the base of the deposit was reached. It will thus be seen that this strange deposit, although it is compact, is very porous, so that the water which falls upon its surface never collects there in ponds, nor does it accumulate within its mass, as it is known to do upon the surface of and within the Drift and stratified formations.

As defined by Dr. White, the eastern limit of this deposit in Iowa has the following course: Beginning with the southeast corner of Fremont county, it follows up the eastern water-shed of the East Nishnabatona to the southern boundary of Cass county; thence to the center of Audubon county; thence to Tip-Top station, on the Chicago and Northwestern railway; thence by a broad curve westward to the northwestern part of Plymouth county.

(*a*) *Geology of Iowa.*

THE FLOYD RIVER.

This is a small stream heading in Sioux and O'Brien counties, in northwestern Iowa. It runs southwesterly, and joins the Missouri at Sioux City. From the source of Willow creek its length by general course is about 70 miles. The area drained comprises 1,014 square miles, and consists of rolling prairie. The river runs through level bottom-land bordered by low hills; the bed and banks are generally of loam, and 5 to 10 feet in height. The current is sluggish in the lower river, but more rapid toward Le Mars. In the latter section the average width is 20 to 30 feet, increasing to 75 or 100 feet for the 10 miles above the mouth. In an ordinary stage, where running freely with straight course, the water is 1 to 2 feet deep. The banks are not often overflowed extensively, but the river has been known to spread out half a mile wide at Le Mars. Near the mouth the ordinary June rise is but a few feet, but in 1867 there was a rise of 22½ feet, said to be the greatest on record.

The river has good railroad facilities, and is closely followed by the Chicago, Saint Paul, Minneapolis and Omaha railway, and by the Illinois Central between Le Mars and the mouth. Sioux City and Le Mars are the principal towns. The first power met in ascending the river is at Sioux City, but a short distance from the mouth, and is used by a flouring-mill having three runs of stone, a brush dam, and 6 to 7 feet head. The pond is 2½ miles long and 75 feet wide. There are small mills, of one or two runs each, at James and at Merrill, and one of four runs at Le Mars. The dam at the latter point sets back the river for 2 miles, in which distance it has an average width of 40 feet, and creates a head of 10 feet. The mill is able to run at full capacity by water-power eight months in the year, but a 30 horse-power steam-engine is used the rest of the time.

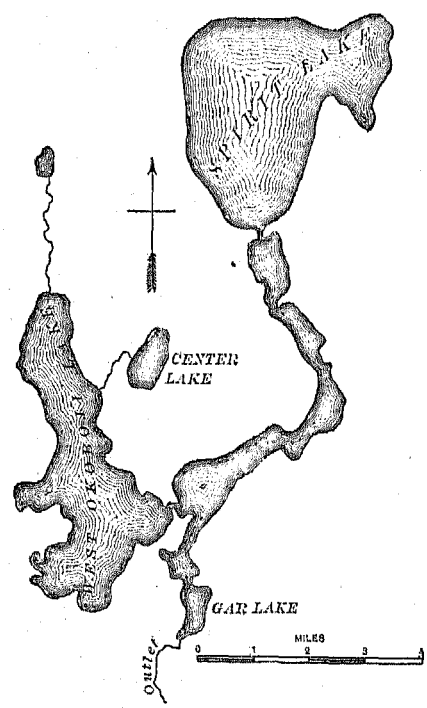
Elevations on Floyd river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Marshall†	1,165.0	57.5	17	3.38
Near mouth‡	1,107.5			

* Map measurement.
† Water surface at Illinois Central railroad crossing.
‡ Water surface at Sioux City and Pacific railroad crossing.

THE LITTLE SIOUX RIVER.

This important milling stream rises in southwestern Minnesota, but a short distance above the boundary between that state and Iowa; entering the latter state it takes a southwesterly course to the Missouri river, which



LAKES NEAR HEADWATERS OF LITTLE SIOUX RIVER.

it reaches some 40 miles to the northward from Omaha. Near its head it receives the waters of Spirit and Okoboji lakes. Spirit lake, the more northerly of the two, lies just south of the state line, and bordering upon it; it is quite regular in shape, and has a surface of 9 square miles. The dividing ridge between Spirit and Okoboji lakes is about 80 feet high, and through this runs the channel which connects the two. Okoboji lake is 2½ to 4 feet lower than its companion, and has approximately the same area; it has a horseshoe shape, with a length, following the bends, of 15 miles. Narrow in the eastern portion, it expands toward the west into what was called by the Indians *Minnetonka*, Sioux for "Great Water". This part of the lake is said to attain a depth of nearly 100 feet at one point. Both the lakes which have been described have gravelly beds, very clear waters, and, with their thickly wooded shores, present a charming appearance.

From its source to the southern part of Cherokee county the course of the Little Sioux lies upon the Drift. In this distance the valley is a quarter to a half mile wide, the bed is gravelly and sandy, the banks are gravelly and rather low, and frequently only 4 to 6 feet high. At Peterson the river is described by Dr. White as passing through a gorge not more than a quarter of a mile wide, in which it lies nearly 200 feet below the surrounding country; yet throughout this depth there is displayed nothing but Drift. Passing down through Cherokee county the region of the Loess is reached, and the valley widens out. The banks are 15 to 20 feet high, and both they and the bed are composed of soft mud. The bottom-land is bordered by bluffs, which continue for 8 miles into Monona county; but below that locality the valley is merged into that of the Missouri. About midway in Monona county the Little Sioux is joined by the West fork and Maple river. At some period in the past these were independent streams, each emptying by itself into the Missouri, which then ran close to the Iowa bluffs; but the Missouri now lies 8 or 10 miles farther west, and the Little Sioux, joined by its two tributaries, runs for a while in the old channel of the Missouri, and then crosses the flood-plain to its present course.

The basin of the Little Sioux lies in the least thickly settled portion of Iowa, and at present the greater part of its course is not adjacent to any railroad. It is crossed, however, at right angles at Cherokee and Spencer, points in its middle and upper course, respectively; and is also crossed by the Sioux City and Pacific line at its mouth. Cherokee, population, 1,500, and Spencer, 800, are the principal towns on its course.

Elevations on Little Sioux river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Feet per mile.*
Cherokee †	1,143	101	79	1.28
Near mouth ‡	1,042			

* Map measurement.
† (565 feet above low water at Dubuque) Illinois Central railroad levels, water surface.
‡ (460 feet above lake Michigan) Sioux City and Pacific railroad levels, water surface.

The surface drained by the Little Sioux has an area of 4,233 square miles. It is a rolling prairie, fertile, and well adapted to corn, wheat, and other grains. Timber is confined to fringes along the streams; a considerable amount is found in the vicinity of Spirit lake, and below that the course of the river is bordered by a moderate amount of cottonwood, oak, and basswood.

In an average stage the river has a current of perhaps 3 miles an hour below Cherokee; its depth in the same stage ranges from 3 to 5 feet between Peterson and the mouth, while the width gradually increases from 40 feet to 60 or 70 feet. Its course is very winding, and it runs back and forth across the bottom land, approaching first one line of bluffs and then the opposite. In its upper course the banks are not commonly submerged to a serious extent; as the mouth is approached, however, the stream becomes more sluggish, perhaps also more crooked, than above, and is subject to a freshet rise of 15 or 20 feet. It is not flashy, and is not much affected by ordinary storms; but in spring, when the snow is melting, and during the heavy summer rains, it is liable to overflow its banks, and in its lower course sometimes spreads out to a width of 2 or 3 miles.

Between Cherokee county and the mouth there is a large fall unimproved, but this portion of the river is neither considered valuable nor utilized, on account of its heavy rises, muddy bed and banks, and the consequent difficulty in maintaining dams. There are rapids in the Sioux just north of the Harrison county line, and there is one small mill, with 4 feet head, returned as using the river for power in that county; but with this exception there is said to be but one mill below Correctionville, and that is a small one at Smithland, having two or three runs and a brush dam. Above Smithland I learned of the following mills: Correctionville, one mill of two runs; 7½ miles below Cherokee, one mill of two runs; 6 miles below Cherokee, one mill of one run; Cherokee, one mill of four runs; Peterson, one mill of two runs; Sweet's mill, two runs; a small mill at Sioux Rapids; one of three runs at Spencer; one of four runs, and one of three runs at Okoboji outlet.

The river is at its lowest stage from December on through the winter, and runs highest usually in June. During high water the mills are troubled by the set-back and consequent loss of head. Their dams were described to me as being in many cases cheaply built of brush, and apt to be cut away, in part at least, by the river. They probably average 100 feet in length by 6 to 8 feet in height.

The power at Cherokee is occupied by a four-run flouring-mill, using about 75 horse-power, with 7 feet fall. There is sufficient water for running at full capacity nine months in the year, but the mill is shut down the remainder of the time. The dam was built in 1871, and is of crib-work, 130 feet long and 7 feet high. The pond is 2½ miles long and averages 100 feet in width and 4 feet in depth.

Of the two mills on the outlet of lake Okoboji the larger carries four runs of stone, and is operated by the Milford Water Power Improvement Company.

Of the tributaries of the Little Sioux, the West fork is not a mill stream; Maple river is in appearance about one-third the size of the main river, and has several flouring- and grist-mills.

THE SOLDIER RIVER.

Rising in Ida county, Iowa, this river runs southwesterly across portions of Crawford, Monona, and Harrison counties, and empties into the Missouri 13 miles south of the Little Sioux. It is 60 miles long by general course, and drains an area of 529 square miles, long and narrow in shape, and measuring only 12 or 14 miles across in the broadest part. There are no important towns on the stream, and it is not touched by any railroad except at its mouth. It is about two-thirds the size of the Boyer river to the south, and has a moderate current, with a bed mainly composed of mud, but showing gravel in some places. The banks are of loam, 10 to 15 feet high, and are overflowed every few years, an extreme freshet rise of 25 feet having been noted. The river might be used for a small power once in a few miles, but at present there are only two mills on its course; these carry about two runs of stone each, and are able to run at full capacity nine months in the year. During the remainder of the time they are troubled by either a low stage or by backwater.

THE BOYER RIVER.

The Boyer river rises in Sac county, and, following the southwesterly direction common to the streams of this section, empties into the Missouri 10 or 12 miles north of Council Bluffs. The area drained is 80 to 90 miles long, 12 to 15 miles wide, and contains 1,123 square miles. From its extreme source the river has a length of about 85 miles by general course. The Chicago and Northwestern railway follows the stream closely below Denison, and along its course are a number of thriving towns, of which the most important are Denison, population about 1,400; Logan, 600; and Missouri Valley, 1,200. Toward the headwaters the country is a flat prairie. The valley of the stream averages about 1½ miles in width, though in places it expands to 3 miles, and is bordered by bluffs 40 to 100 feet high. No lakes are drained, and the surface of the country is not suited to storage reservoirs.

In an ordinary stage the Boyer is 50 to 60 feet wide and 2 feet deep, with a moderate current. The bed is mostly mud, but occasionally gravel. At only one point does rock appear, and that is in the vicinity of Logan; here are a few exposures of limestone belonging to the Upper Coal Measures, their only occurrences in Harrison county, and the most northerly of the kind in Iowa. The lowest stratum of this exposure is 3 to 4 feet thick, and consists of a compact, light-gray limestone, with clay partings. It is well suited to building purposes, and at several points near Logan has been quarried and used. The river banks are of loam, and rise 10 to 15 feet above low water. Once in a few years the Boyer overflows its banks, and spreads out from bluff to bluff; the highest rise noted in the lower river was about 25 feet, or at least 10 feet above the general level of the banks.

The use of water-power is confined to flouring-mills, which, I was informed, are located as follows, ascending the stream: Loveland, one mill of four runs, with timber dam; Logan, one mill of two runs; Woodbine, one mill of two runs, with brush dam; Dunlap, one mill of three runs. There are also mills at Dow City, Denison, and Mason's Grove. These mills have, in general, a fall of 7 or 8 feet, and surplus power during a portion of the year; for two or three weeks they are troubled by backwater.

At Logan, power is used by a flouring-mill of two runs, with two wheels under a head of 8 feet. The dam was built in 1856, and is of stone, 60 feet long, 8 feet high, and 8 feet wide at the top; it rests upon a limestone ledge, and abuts upon rock at one end and upon a masonry wall at the other; it has no apron. The supply of water is sufficient for running at full capacity eight months in the year, and two-thirds capacity the rest of the time.

It is considered that the Boyer would furnish power for four or five runs of stone during the greater part of the year; less than half the fall of the stream below Denison is now employed, and numerous sites might be found both below and above that point, where a head of 7 or 8 feet could be secured.

Elevations on Boyer river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Denison†	1,162	72	22	3.27
Near Dunlap†	1,090			
Mouth of river‡	1,014	76	37	2.05

*Map measurement. †Water surface by Chicago and Northwestern railway levels. ‡Estimated.

THE MOSQUITO RIVER AND KEG CREEK.

These are the next tributaries of the Missouri below the Boyer river. Mosquito river is 60 miles long by general course, and toward the mouth is 20 or 30 feet wide in an ordinary stage and 3 feet deep. The bed is muddy, the banks are of loam, and 10 feet in height. The current is moderate in the upper course, but sluggish as the Missouri is approached. The banks are occasionally overflowed, and in the dry season the stream runs very low. It is used for power by two flouring- and grist-mills, but has not much value. Keg creek is a small stream of no special importance, but has three flouring-mills.

THE NISHNABATONA RIVER.

This river is formed by two forks, the East and the West, which rise 60 to 70 miles northeast of Council Bluffs, and, flowing southerly, unite in Fremont county. The main river is only about 30 miles long by straight course. It formerly emptied into the Missouri near Hamburgh, in the southwestern corner of Iowa, but work done ten or twelve years ago, in connection with the Kansas City, Saint Joseph and Council Bluffs railroad, changed its course, so that it now enters the Missouri in Atchison county, Missouri, 20 miles to the southeast of its old mouth.

The entire area drained by the Nishnabatona is 3,100 square miles, of which 1,146 belongs to the East Fork and 1,678 to the West Fork. The country is rolling and very fertile, corn, wheat, and other grains being the chief productions. Limestone is found, and good brick clay. Borings have been made for coal, but it seems to lie too deep to be successfully worked. The old growth of timber has been mostly cut away, but there is an abundance of young growth, mostly soft maple and elm. The main river is 150 feet wide in an ordinary stage. There are no mills upon its course, and it is not probably of much value for water-power, on account of slight fall and backwater from the Missouri. It strikes into the broad bottom of the latter stream at Hamburgh, a place of about 2,000 inhabitants.

The East Nishnabatona is about 100 miles long by general course. Its immediate valley is 1 to 3 miles in width, and shows a gradual rise to the bluffs, which reach elevations of 50 to 200 feet above the river. A branch of the Chicago, Burlington and Quincy railroad follows the stream from its mouth through the greater part of its course, and it is also crossed by railroads at three points in directions at right angles to its own. Red Oak and Atlantic are the principal towns on the river, the former with a population of about 3,800, and the latter with 3,700. The width of the stream in an ordinary low stage increases from 75 feet at Red Oak to 100 feet at the mouth, and the depth from 3 feet to 5 or 6 feet. The only mill in Fremont county on the lower river is a mile and a half north of Farragut. It carries three runs of stone, and has a frame dam resting on piles. In this section of the river the bed is muddy, the banks are of loam, and 5 to 10 feet high. There is a moderate fall, and the stream has a good current; it is subject to an extreme freshet rise of about 8 feet, and once in every few years overflows its banks and spreads out in places from bluff to bluff.

Ascending the stream the next power is in use at Heiner's mill, 1 mile south of Red Oak. The dam was built in 1867, and is 90 feet long by 7 feet in height. It rests upon a foundation of gravel, clay, and sand, and abuts upon a crib-work at one end and upon a mass of brush and earth at the other. The structure itself is of brush, and gives a head of 7 feet. The pond is claimed to extend 7 miles up the river. Heiner's mill has three runs of stone, and wheels of 60 horse-power. It can commonly be run at full capacity throughout the year, and the proprietor considers his privilege good, in general, for five runs of stone at the lowest stage of river.

The East Nishnabatona has in this section a muddy bed, with occasional rock ledges. The banks are of loam, and 10 to 15 feet high. Every few years the bottoms are extensively overflowed, and nearly every year in low places. The extreme freshet rise is about 18 feet. There are mills at points 2 miles and 9 miles above Red Oak, and some others above, but only a small portion of the fall of the stream has been developed.

Elevations on East Nishnabatona river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Atlantic†	1,128	124	37	3.35
Red Oak‡	1,004	43	22	1.95
Near Shenandoah§	961	63	61	1.03
Near mouth main river‖	898			

* Map measurement.
† Chicago, Rock Island and Pacific railway crossing.
‡ Chicago, Burlington and Quincy railroad crossing.
§ Water surface at Wabash, Saint Louis, and Pacific railway crossing.
‖ Water surface at Kansas City, Saint Joseph and Council Bluffs railway crossing.

The West Nishnabatona is very similar to the East Fork. The bottom-land bordering it averages 2 miles in width, and is in places 3½ miles wide. To the east of Council Bluffs the river averages 75 feet across at an ordinary

stage, with a depth of 5 to 8 feet. The bed is mostly mud, with occasionally gravel and rock; the banks are of loam, and 15 to 20 feet high. This stream has a moderately swift current, and sometimes overflows its banks during severe freshets. Both the West and the East Forks are muddy streams, and especially so after heavy rains. They have a tolerably steady flow, and are not very rapid in rise and fall. They are very crooked and sluggish in their lower courses. High water occurs from April to June, and is followed by a decreasing volume, with low water in August and September. There are only 3 mills on the West Fork—one in Shelby county, and two in Pottawattamie county. A still less proportion of the fall of this stream has been developed than of the East Fork, the reasons for the small use of power in this section being claimed to be a lack of demand for mills, and a scarcity of capital. The West Nishnabatona has good railroad facilities, and is followed closely by a branch of the Chicago, Burlington and Quincy railroad. The larger towns adjacent to its course are Sidney, population about 900; Avoca, 1,600; and Harlan, 1,300.

Elevations on West Nishnabatona river.

Locality.	Elevation above sea.	Fall between points.	Distance between points. *	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Avoca †	1,103	119	39	3.05
Near Lawrence ‡	984			
Near mouth of main river §	898	86	60	1.30

* Map measurement.
† Chicago, Rock Island and Pacific railway crossing.
‡ Water surface at Wabash, Saint Louis and Pacific railway crossing.
§ Water surface at Kansas City, Saint Joseph and Council Bluffs railroad crossing.

Walnut river and Silver creek are the only important tributaries of the West Nishnabatona, and are both employed for power by a few flouring- and grist-mills. Walnut river joins the main stream from the east about 7 miles above its mouth. It has a muddy bed, and banks of loam, rather low in places. In an ordinary stage this stream is 50 feet wide, 5 feet deep, has a moderately swift current, and is of fair value for small powers.

The average rainfall over that portion of western Iowa which has been considered is not far from 8 inches in spring, 14 in summer, 8 in autumn, and 3 in winter, making 33 inches for the year. It is rather less, however, in the northern part of the district. Having been unable to find any records whatever of gaugings of the streams, I have prepared rough estimates of their volumes, which are given in the accompanying table, and may be of some service in showing their capabilities for power.

Estimated volume and horse-power of the Western Iowa tributaries of the Missouri river.

Stream.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.			LOW WATER, AVERAGE YEAR.			AVAILABLE 10 MONTHS IN AVERAGE YEAR.		
		Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
Floyd:	*Sq. miles.*									
At Le Mars	481				0.040	20	23	0.070	30	34
At mouth	1,014	0.020	20	23	0.040	40	46	0.070	70	80
Little Sioux:										
At Sioux Rapids	1,362	0.030	40	46	0.040	50	57	0.070	95	108
At Cherokee	2,075	0.030	60	68	0.040	80	91	0.070	145	165
At Correctionville	2,445	0.030	70	80	0.040	100	114	0.070	170	194
At mouth	4,233	0.030	130	148	0.040	170	194	0.070	300	342
West Fork	625	0.020	10	11	0.040	25	28	0.070	40	46
Maple river	819	0.025	20	23	0.040	30	34	0.070	60	68
Soldier:										
At Hall creek	382				0.050	20	23	0.080	30	34
At mouth	529	0.020	10	11	0.050	30	34	0.080	40	46
Boyer:										
At Crawford	546	0.020	10	11	0.040	20	23	0.060	30	34
At Logan	834	0.025	20	23	0.040	30	34	0.060	50	57
At mouth	1,123	0.030	30	34	0.040	45	51	0.060	70	80
Mosquito river	285							0.060	20	23
Keg creek	324							0.060	20	23
Nishnabatona:										
At Riverton	2,824	0.040	110	125	0.060	170	194	0.080	230	262
At mouth	3,100	0.040	120	137	0.060	190	217	0.080	250	285
East Fork:										
At Red Oak	409	0.050	20	23	0.080	30	34	0.100	40	46
At mouth	1,146	0.050	60	68	0.080	90	103	0.100	115	130

Estimated volume and horse-power of the Western Iowa tributaries of the Missouri river—Continued.

Stream.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.			LOW WATER, AVERAGE YEAR.			AVAILABLE 10 MONTHS IN AVERAGE YEAR.		
		Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
West Fork:	*Sq. miles.*									
At Nishna	605	0.025	15	17	0.050	30	34	0.070	40	46
At Hastings	984	0.030	30	34	0.050	50	57	0.070	70	80
At mouth	1,078	0.030	50	57	0.050	80	91	0.070	120	137
Walnut river	245				0.040	10	11	0.080	20	23
Silver creek	250				0.040	10	11	0.080	20	23

Power utilized on the Western Iowa tributaries of the Missouri river.

Stream.	Tributary to what.	State.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Floyd	Missouri	Iowa	Woodbury	Flour and grist	1	10	50
Do	do	do	Plymouth	do	1	12	11
Little Sioux	do	do	Harrison	Flour, grist, and saw	1	4	57
Do	do	do	Woodbury	do	8	22	162
Do	do	do	Cherokee	Flour and grist	3	10	144
Do	do	do	Buena Vista	do	2	17	106
Do	do	do	Clay	do	2	16	184
Maple	Little Sioux	do	Monona	do	3	22	120
Do	do	do	Ida	do	2	18	62
Small streams	do	do	Woodbury	do	1	35	40
Do	do	do	do	Carpentering	1	22	5
Do	do	do	Cherokee	Flour and grist	1	8	15
Do	do	do	Dickinson	do	2	30½	62
Soldier	Missouri	do	Harrison	do	2	13	57
Boyer	do	do	do	do	2	20	95
Do	do	do	Crawford	do	3	25	84
Do	do	do	Sac	do	2	18½	25
Small streams	Boyer	do	Harrison	do	1	8	18
Do	do	do	Crawford	do	1	8	20
Pigeon	Missouri	do	Pottawattamie	do	1	11	28
Mosquito	do	do	do	do	2	18	90
Keg	do	do	Mills	do	3	33	108
Small stream	do	do	Fremont	do	1	20	8
East Nishnabatona	Nishnabatona	do	Montgomery	do	3	22	118
Do	do	do	Cass	do	2	18	76
Do	do	do	Audubon	do	2	18½	40
Small streams	East Nishnabatona	do	Cass	do	2	19	86
West Nishnabatona	Nishnabatona	do	Pottawattamie	do	2	14½	60
Do	do	do	Shelby	do	1	8	45
Walnut	West Nishnabatona	do	Fremont	do	4	43	154
Do	do	do	Montgomery	do	1	10	20
Silver	do	do	Mills	do	3	23	95
High	Nishnabatona	Missouri	Atchison	do	1	8	26
Rock	do	do	do	do	2	35	44
SUMMARY.							
Floyd	Missouri	Iowa			2	22	61
Little Sioux	do	do			11	78	603
Tributaries	Little Sioux	do			10	135½	304
Soldier	Missouri	do			2	13	57
Boyer	do	do			7	63½	204
Tributaries	Boyer	do			2	16	38
East Nishnabatona	Nishnabatona	do			7	58½	234
Tributaries	East Nishnabatona	do			2	19	86
West Nishnabatona	Nishnabatona	do			3	22½	105
Tributaries	West Nishnabatona	do			8	76	269
Small streams	Nishnabatona	Missouri			3	43	70
Do	Missouri	Iowa			7	82	234
Total					64	629	2,265

TRIBUTARIES OF THE MISSOURI RIVER IN NORTHERN MISSOURI.

The streams which I shall describe under this head extend from the Nishnabatona on the west, to the Chariton on the east, and include the latter; below the Chariton the Missouri receives no tributaries of any importance from the north. They rise in southern Iowa and run southerly into Missouri, the principal portions of their courses lying in the latter state. The section of country which they drain is rich farming land, contains beds of coal and limestone, and has a fair amount of timber, covering, perhaps, one-fourth of the surface, which is everywhere rolling. Corn and wheat are largely raised, and in some counties fine crops of tobacco are produced. The means of communication are good; numerous lines of railway run north and south, east and west. To the east and south are the Mississippi and Missouri rivers, navigable, and constantly drawing more and more attention to their improvement.

The rivers to be discussed are not navigable, and in only one or two cases are they much used for rafting. They are employed to a considerable extent for power by flouring- and grist-mills, and answer moderately well for such use. They are not, however, suited to purposes of general manufacturing of much importance. They are subject to heavy overflows in the spring or early summer, while in the late summer or fall they run extremely low. Through the more important portions of their courses they have but a slight fall and are winding and sluggish. The beds and banks are usually muddy, and the common tendency toward a low bank on one side, while the opposite one is of normal height, renders it often difficult to find a suitable location for a dam, or to prevent overflowing the banks by backwater from the mill-ponds.

THE BIG TARKIO RIVER.

This stream heads in Page and Montgomery counties, in southwestern Iowa, and, flowing southerly, passes through Atchison and Holt counties, Missouri, and joins the Missouri river. It drains 543 square miles, and has a length, by general course, of 75 or 80 miles. For a considerable distance above the mouth it runs through the Missouri river bottom, and has no separate valley; but farther up stream it is bordered by bottom-land which forms its own distinct valley, 1 mile to 1½ miles in width, and bounded by bluffs of moderate height. In ordinary low water the Tarkio is about 125 feet wide in its lower course, and 2 to 3 feet deep. The banks are of loam, 10 to 12 feet high. It is a muddy stream, with a moderate current when low, but flows rapidly in high water. It gets very low in summer, and on account of its small volume and slight declivity has not much value for power. Rising more rapidly after heavy rains than the Nodaway, which lies next east, it has a range of perhaps 10 feet between low and high water; occasionally it rises 2 or 3 feet above its banks and submerges the bottom-land. The number of mills employing this stream for power and its estimated volume will be given in subsequent tables.

Elevations on Big Tarkio river.

Locality.	Elevation above sea.	Fall between points.	Distance between points. *	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Snow Hill, Page county, Iowa †.	979	109	35	3.12
Craig, Holt county, Missouri ‡.....	870			

* Map measurement.
† Water surface at Wabash, Saint Louis and Pacific railway crossing.
‡ Water surface at Kansas City, Saint Joseph and Council Bluffs railroad crossing.

THE NODAWAY RIVER.

The Nodaway is formed by small streams having their sources in Cass and Adair counties, in southwestern Iowa; it runs southerly and empties into the Missouri 10 miles north of Saint Joseph. Its basin is quite narrow in Missouri, but expands somewhat toward the headwaters in Iowa, and has an area of 1,886 square miles. From the head of the Middle Fork to the mouth of the main stream the distance by general course is 120 miles. The valley of the stream varies from a quarter of a mile to 3 miles in width, and is bordered by bluffs 100 to 200 feet high. Corn is the chief production of the bottom-land, and corn and wheat of the upland. Considerable timber, mostly oak, is found for the first 10 or 12 miles above the mouth, but not a great deal beyond. Limestone, well suited to building, occurs along the course of the river, also an inferior quality of brick clay; no coal is obtained near the mouth, and but little above.

The river bed is fine mud, and the banks are of loam, 10 to 12 feet high; rock is seldom found, except on one side, where a bluff has been cut into by the current. There is no navigation, no rafting, and the only use, in fact, to which the stream is put is to furnish power to flouring- and grist-mills, of which there are quite a large number, leaving but a small amount of fall unutilized below Villisca. It is said that the mills on the lower river can

commonly run at full capacity throughout the year, though in the dry season the river is very low and they do not probably have much surplus power. The lowest mill has backwater from the Missouri when the latter is high. The streams of northwestern Missouri are claimed to have much deteriorated since the settlement of the country; they formerly ran with full banks, but the cutting away of the timber and the cultivation of the soil have sensibly lessened their low-water volumes; springs have diminished and the soil has washed in and filled up their beds.

Elevations on Nodaway river.

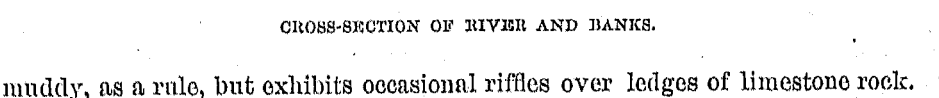
Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near Villisca†	1,001	87	32	2.72
Near Claremont‡	914			
Near mouth§	841	73	59	1.24

* Map measurement. † Chicago, Burlington and Quincy railroad crossing.
‡ Water surface at Wabash, Saint Louis and Pacific railway crossing.
§ Water surface at Kansas City, Saint Joseph and Council Bluffs railway crossing.

THE PLATTE RIVER OF MISSOURI.

Formed by small streams rising in Union and Adams counties, in southwestern Iowa, the Platte enters Nodaway county, Missouri, and keeping a southerly direction empties into the Missouri river in southern Platte county. From its extreme source it has a length, by general course, of 140 miles, and drains an area of 2,487 square miles. Its principal tributary is One Hundred and Two river, which joins it 6 miles east of Saint Joseph. This section has fine railroad facilities; several important lines cross the river at various points, and a branch of the Chicago, Burlington and Quincy railroad follows a considerable portion of the course of One Hundred and Two river. The more important towns are, on Platte river, Platte City, population about 700; on One Hundred and Two river, Savannah, population, 1,200; Maryville, 3,500; Hopkins, 900; and Bedford, 1,800.

The valley of the Platte is very fertile, corn being the chief production of the bottom-land, and corn and wheat of the upland. There was formerly a heavy growth of timber, comprising white oak, burr oak, ash, hickory, maple, and locust, but it has been largely cut away within the past few years on the lower river; in Andrew county considerable amounts of oak, elm, and hickory still remain. In Platte county, near the mouth, inferior qualities of brick clay and limestone for building are found, and here and there a little coal. The river is muddy at nearly all times, and in high water carries much drift; a good business is done in rafting logs and railroad ties down to Platte City, and small craft are able to ascend the stream to that point. The lower valley averages 2 miles in width, and is flanked by bluffs 200 feet high. The stream itself is, in Andrew county, 75 to 90 feet in width, in an ordinary stage, and 3½ to 4 feet deep; at Platte City it runs 150 feet wide in ordinary low water, and 3 to 5 feet deep, while in mean high water the corresponding dimensions are 300 feet and 15 feet. The banks are of loam, and average 15 feet in height throughout the lower portion of the river. Although this is the normal height, and usually reached by one bank or the other, the opposite one is almost invariably low, from the action of the river in cutting away its banks, shifting its channel, and building bars, and a cross-section is produced as illustrated in the



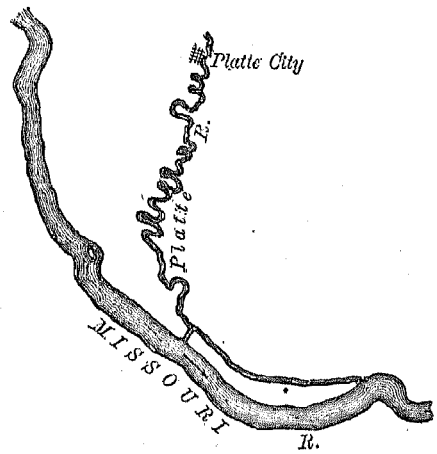
CROSS-SECTION OF RIVER AND BANKS.

cut. The bed is muddy, as a rule, but exhibits occasional riffles over ledges of limestone rock. The river is very crooked, and in low water has a sluggish current, which becomes rapid as a high stage is again approached.

The Platte never runs dry, though it reaches a very low stage in September and October. It is subject to very sudden rise and fall after heavy storms, and sometims rises several feet in a few hours. High water occurs in May and June, and sometimes also in the fall. The lower river is liable to an extreme freshet rise of about 25 feet, and once in five or ten years overflows its banks, spreading out in places from bluff to bluff, and running from a mile to a mile and a half in width.

The lowest mill on the river is at Platte City, 20 miles northwest of Kansas City. The dam was built in 1874, and is 100 feet in length by 7 feet in height. It is an open framed structure resting upon a bed of limestone, to which it is bolted down. It abuts at one end upon a log crib-work filled with stone, and at the other end upon the timber wall of the race; it is not provided with an apron. The pond extends 3 miles up the river. The mill carries three runs of stone, and has wheels of about 70 horse-power, working under a head of 7 feet. There is sufficient

water for running at full capacity eight months in the year, but the mill is stopped for two months by backwater, and for another period of two months can only run at about one-third capacity on account of low water. The old mouth of the Platte was farther down the Missouri than the present one, but the latter stream cut into its course and gave it a new outlet. Since that occurrence there has been 5 feet more dead-water at Platte City than before, and the mill at that point has suffered accordingly.



SKETCH SHOWING CUT-OFF.

There is only one other improved power on this river in Platte county, and that is occupied by the Union Mills, carrying two or three runs and having a frame dam filled with stone, resting upon a rock ledge. Farther up stream there are mills at frequent intervals, but I did not learn their exact locations; they will be given by counties in a subsequent table. The dams are said to be usually brush or framed structures, and to give a fall, in general, of about 8 feet. A large proportion of the fall of the Platte and One Hundred and Two rivers remains unimproved, mainly from a lack of demand for power.

One Hundred and Two river runs parallel to the main stream, and much of the way is distant but a few miles from it to the west. In an ordinary stage of water it is 80 to 90 feet wide in Andrew county, and 3 or 4 feet deep. It is bordered by considerable timber, but is not used for rafting. The bed is generally mud, but once in 3 miles, on an average, there is a riffle with rock bottom. The banks are of loam, and are about 15 feet in height above low water. The volume holds out better in the dry season than in the case of the main stream, still the river runs very low for six weeks or two months in late summer and fall. There is only a moderate current during a low stage, but in high water the stream is quite swift; once in several years it overflows the banks and runs 18 feet deep. It is considered to have fair value for power, and mills are located at the following points as you ascend the river: Avenue City, one mill of three runs; Phillips' mill, east of Savannah, two runs; Rosendale, one mill of three runs; Barnard, one mill of three runs; near Arkoe, one mill of two runs; Bedford, Iowa, one mill. There are probably one or two others not included in this list. The dams are said to be usually brush or framed structures, giving a fall of about 8 feet. The brush dams are built in the common manner—a layer of trees on the river bed, with successive layers of brush and stone above.

Elevations on Platte and One Hundred and Two rivers.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
Platte river.	*Feet.*	*Feet.*	*Miles.*	*Ft. per mile.*
Near Conception†	1,076	269	62	4.34
Near Frazier†	807	52	57	0.91
Near mouth‡	755			
One Hundred and Two river.				
Near Hopkins‡	1,048	145	35	4.14
Near Rosendale‡	903	148	94	1.57
Near mouth Platte‡	755			

*Map measurement.
†Water surface at Wabash, Saint Louis and Pacific railway crossing.
‡Water surface at Kansas City, Saint Joseph and Council Bluffs railroad crossing.

THE GRAND RIVER.

The Grand river is formed by a number of small streams which rise in the southwestern counties of Iowa, 30 to 50 miles above the state line. Flowing southerly into Missouri, they finally combine into two principal forks—the East and the West—which themselves unite near Chillicothe, in Livingston county; the main river then takes a southeasterly course for 35 miles to the Missouri river, which it joins at Brunswick, on the western border of Chariton county. From the source of the West Fork, in Union county, Iowa, to the mouth of the main stream, the distance by general course is 140 miles. The total area drained by Grand river is 7,932 square miles. The surface is a rolling prairie, well timbered along the streams with cottonwood, elm, hickory, and walnut. Limestone exists plentifully in the bluffs, and sandstone crops out in at least one locality. The country is quite well settled, and has good railroad communications. The Wabash, Saint Louis and Pacific railway strikes the West Fork in Gentry county, and continues down the valley and to the mouth of the main river; some of the other tributaries are similarly followed by different lines. The more important places on the streams are: on the Grand, Brunswick, population, 1,800, and Chillicothe, 4,100; on the West Fork, Gallatin, 1,100, and Albany, 1,000; on the East Fork, Trenton, 3,300; and Princeton, 1,200; on Locust river, Linneus, 900.

Both the East and the West Forks are in their lower courses bordered by rich farming land, but the "first bottom" is injured for agricultural purposes by its liability to overflows, which occur nearly every year and sometimes several times in a single year. The valley of the East Fork is rather broader than that of the other, and averages 1 to 2 miles in width. Both rivers have beds principally composed of mud, sand, and gravel, and contain very few rock ledges. Their banks are of alluvial soil, and average 20 feet in height above low water, being usually high on one side and low on the opposite. The country drained is very deficient in springs, and the streams have, therefore, to depend chiefly upon surface drainage to maintain their flow. The East and West Forks are very sluggish in their lower portions, and very few riffles are to be seen; levels have been run along the former near Chillicothe, revealing a fall of about 6 inches to the mile. This stream averages a little more than 100 feet in width near its mouth, and for four or five months in the year is 2 to 3 feet deep on the riffles; it has a very crooked course. The West Fork is straighter and also somewhat wider, averaging 150 feet across.

Ascending from the Missouri, the first power in use is at Graham's mill, on the East Fork. The dam is in part framed and in part built of logs, and is filled in with loose stone; it rests upon rock for a portion of the distance across the river, and has abutments of crib-work filled with stone. The length of the structure is 112 feet, its height 8 feet, and its cost was about $1,000. The river bed is protected from scour by an apron of hewn timber, extending under the entire dam and projecting 10 feet below it down stream. Graham's mill can be run at full capacity eight months in the year, but for two months it is stopped by backwater, sometimes for six weeks at a single stretch, and for an additional period of two months low water prevents running at more than about one-half capacity. Three runs of stone are carried, power being furnished by three water-wheels of 12 horse-power each.

There are no mills below Chillicothe, though there is said to be a fine unimproved site at Bedford, a little place some 25 miles above the mouth of the river, and beyond the reach of backwater from the Missouri. Above Chillicothe there are flouring- and grist-mills at frequent intervals on both forks, although a large part of the fall of each still remains undeveloped. The dams on these streams are usually brush or framed, rest upon mud or gravel beds, and yield heads of 7 or 8 feet. The brush dams are constructed of brush and saplings laid with the stream, cross-logs for binders, and stone filling; they stand well and give very good satisfaction. The mills on the East Fork are stated to have their principal trouble from backwater; those on the West Fork have less difficulty from that source, but are troubled to a greater extent by a scarcity of water in the dry season.

Elevations on Grand river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
West Fork and main river.	*Feet.*	*Feet.*	*Miles.*	*Ft. per mile.*
Near Gentryville†	816	136	76	1.79
Mouth Weldon river‡	680			
Mouth Grand river†	635	45	52	0.87
East Fork.				
Four miles east of Afton, Iowa§	1,005	322	145	2.22
Near Chillicothe†	683			

* Map measurement.
† Water surface at Wabash, Saint Louis and Pacific railway crossing.
‡ Estimated.
§ (500 feet above low water at Burlington) Chicago, Burlington and Quincy railway levels.

THE CHARITON RIVER.

This stream has its sources in Clarke and Wayne counties, in southern Iowa, about 20 miles north of the Missouri boundary. Entering the latter state it runs southerly, and empties into the Missouri river at the southern extremity of Chariton county. It is 150 miles long by general course, and drains 2,900 square miles. It is crossed at frequent intervals by important east-and-west railway lines, and a division of the Wabash, Saint Louis and Pacific road follows up its eastern water-shed, distant most of the way less than 10 miles from the river. Chariton, near the headwaters, is the only important place directly upon the river; but below that point are Centerville, in Appanoose county, Iowa, having a population of 2,500, and distant 5 miles from the river to the west; Kirksville, Adair county, Missouri, 2,300 inhabitants, and lying 5 miles east of the river; Keytesville, 12 miles from the mouth, and distant but 1 mile from the river's course.

Elevations on Chariton river.

Locality.	Elevation above sea.	Fall between points.	Distance between points. *	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Chariton, Iowa †	1,030	281	105	2.68
West of Kirksville, Missouri ‡	749			
Near Keytesville ‡	627	122	81	1.51

* Map measurement.
† (525 feet above low water at Burlington) Chicago, Burlington and Quincy railroad levels.
‡ Water surface at Wabash, Saint Louis and Pacific railway crossing.

In its lower course the valley of the Chariton averages 3 miles in width, and is well timbered with water-oak, burr-oak, hickory, maple, and birch. The river itself is 125 feet wide, and is a sluggish stream, with only occasional riffles; no rafting is done, and the channel is much choked with permanent accumulations of drift, called "rack-heaps". The bed is very muddy, and the banks are of alluvial soil, ranging from 10 to 20 feet in height above low water. Where the stream has cut into a bluff the bed is rocky on that side. A good quality of coal is found in the bluffs, and 9 miles above Glasgow (near the mouth) it crops out for 180 yards, and is 20 inches thick.

The flow of the stream is said to hold out very well in the dry season. Heavy freshets occur, as usual with the streams in this section, and the bottoms are occasionally overflowed. There are some small saw- and grist-mills on the minor tributaries, and two or three on the main river, but the latter is practically unused. The saw-mills are generally run by steam. A gentleman at Keytesville, familiar with the portion of the river in Chariton county, stated that in the dry season it would carry a three-run mill, but without affording much surplus power; he also said there were five available mill-sites in that county on the stream.

Regarding the upper portions of the Chariton and Grand rivers Dr. White says, in the *Geology of Iowa:*

> Both rivers rise and run for the first 25 or 30 miles of their courses upon the Drift deposit alone. The first strata that are exposed by the deepening valleys of both these streams belong to the Upper Coal Measures, and they both continue upon the same formation until they make their exit from the state, near the boundary of which they have passed nearly or quite through the whole thickness of that formation down to the top of the Middle Coal Measures. Therefore, as might be expected, both these streams are very similar in their general characters so far as their Iowa portions are concerned. Their valleys are usually pretty well defined; but sometimes the surrounding high land slopes for a mile or more gently toward the stream. They gradually deepen from their upper portions downward, so that within 15 or 20 miles they have reached a depth of nearly 150 feet below the general level of the adjacent high land, which depth they retain with little increase until they pass beyond the limits of the state, because the general slope of the country is nearly concurrent with the slope of the streams.

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Estimated volume and horse-power of the Northern Missouri tributaries of the Missouri river.

Stream.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.			LOW WATER, AVERAGE YEAR.			AVAILABLE 10 MONTHS IN AVERAGE YEAR.		
		Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Cubic feet per second per square mile.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.									
Big Tarkio:										
West of Homer	416	0.025	10	11	0.040	15	17	0.070	30	34
At mouth	548	0.025	15	17	0.040	20	23	0.070	40	46
Nodaway:										
At Hepburn	756	0.025	20	23	0.040	30	34	0.070	50	57
At Quitman	1,409	0.025	40	46	0.040	60	68	0.070	100	114
At mouth	1,886	0.025	50	57	0.038	70	80	0.070	130	148
Platte:										
At Conception	501	0.030	15	17	0.030	15	17	0.060	30	34
Above One Hundred and Two river	707	0.025	20	23	0.030	20	23	0.060	40	46
At mouth	2,487	0.015	40	46	0.020	50	57	0.040	100	114
One Hundred and Two river:										
At Maryville	517	0.030	15	17	0.030	16	17	0.060	30	34
At mouth	784	0.025	20	23	0.030	25	28	0.060	45	51
Grand:										
At Chillicothe	4,035	0.015	75	85	0.020	100	114	0.040	200	227
At mouth	7,032	0.015	120	136	0.018	140	160	0.035	280	318
West Fork:										
At Albany	406				0.020	10	11	0.050	20	23
At Gallatin	2,241	0.015	30	34	0.020	45	51	0.045	100	114
At mouth	2,678	0.015	40	46	0.020	50	57	0.045	120	136
Big river, at Elm Flat	323							0.030	10	11
Thompson's fork, above Weldon river	1,155	0.015	20	23	0.020	20	23	0.045	50	57
Weldon river, above Thompson's fork	597	0.015	10	11	0.020	10	11	0.040	25	28
Total, East Fork:										
At Trenton	1,752	0.015	30	34	0.020	35	40	0.040	70	80
At Chillicothe	2,257	0.015	35	40	0.020	45	51	0.045	100	114
Medicine river	443							0.030	10	11
Locust creek	615							0.030	20	23
Yellow creek	600							0.030	20	23
Chariton:										
East of Centerville	685	0.030	20	23	0.040	30	34	0.080	55	63
West of Kirksville	1,394	0.020	30	34	0.025	35	40	0.055	75	86
At Hannibal and Saint Joseph railroad crossing.	1,684	0.020	30	34	0.025	40	46	0.055	90	103
At mouth	2,000	0.020	60	68	0.025	70	80	0.055	160	182

The rainfall appears to vary considerably in its distribution among the different seasons, over the country drained by these rivers, but, for the section as a whole, may be regarded as approximately 8 inches in spring, 12 in summer, 8 in autumn, and 5 in winter, giving a total of 33 inches for the year. The average winter temperature for the same district is about 28° Fahrenheit.

Power utilized on the Northern Missouri tributaries of the Missouri river.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Big Tarkio	Missouri	Missouri	Atchison	Flour and grist	2	15	66
East Tarkio	Big Tarkio	do	do	do	1	11	22
Do	do	Iowa	Page	do	2	20	45
Little Tarkio	Missouri	Missouri	Holt	do	1	14	10
Nodaway	do	do	do	do	1	8	20
Do	do	do	Andrew	do	1	6	30
Do	do	do	Nodaway	do	4	25	103
Do	do	Iowa	Page	do	3	21	82
Do	do	do	Montgomery	do	2	24	54
Do	do	do	Cass	do	1	9	20
Small streams	Nodaway	Missouri	Holt	do	1	30	20
Do	do	do	Nodaway	do	1	6	16
Do	do	Iowa	Page	do	1	8	24
Middle Nodaway	do	do	Adams	do	3	22	80

Power utilized on the Northern Missouri tributaries of the Missouri river—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Platte	Missouri	Missouri	Platte	Flour and grist	2	18	103
Do	do	do	Buchanan	do	3	23	136
Do	do	do	Andrew	do	4	37½	145
Do	do	do	do	Saw	1	3½	10
Do	do	do	Nodaway	Flour and grist	1	14	70
Do	do	do	Worth	do	1	8	18
Do	do	Iowa	Taylor	do	1	10	25
Do	do	do	Ringgold	do	1	8	23
One Hundred and Two river	Platte	Missouri	Buchanan	do	2	21	125
Do	do	do	Andrew	do	3	23½	65
Do	do	do	Nodaway	do	3	20½	93
Small streams	do	do	Clay	do	1	9	50
West Grand	Grand	do	Livingston	do	1	8	24
Do	do	do	Daviess	do	3	(?) 21	100
Do	do	do	Gentry	do	3	19	76
Do	do	do	Worth	do	2	14	40
Small streams	West Grand	do	do	do	1	10	30
East Grand	Grand	do	Livingston	do	3	23½	95
Do	do	do	Grundy	do	2	14½	40
Thompson's fork	East Grand	do	Harrison	do	2	14	150
Do	do	Iowa	Decatur	do	3	22	95
Do	do	do	Union	do	1	9	10
Weldon	Thompson's fork	Missouri	Mercer	do	2	15½	94
Do	do	Iowa	Decatur	do	1	5	10
Medicine	Grand	Missouri	Livingston	do	1	8	14
Do	do	do	Grundy	do	2	17½	30
Locust	do	do	Linn	do	3	28	90
Do	do	do	Sullivan	do	3	25	86
Small streams	do	do	Caldwell	do	2	16	15
Do	do	do	Carroll	do	2	20	52
Chariton	Missouri	do	Macon	Flour, grist, and lumber	1	0	51
Do	do	Iowa	Appanoose	Flour and grist	1	10	37
Mussel fork	Chariton	Missouri	Chariton	do	2	18	60
Do	do	do	do	Flour, grist, and lumber	1	7	57
Do	do	do	Macon	Saw	1	0	10
Small streams	do	do	Chariton	do	1	0	25
Do	do	do	Randolph	do	1	0	25
Do	Missouri	do	Holt	Flour and grist	1	30	10
Do	do	do	Platte	do	2	20½	36
Do	do	do	Carroll	do	2	12	45
Do	do	do	Boone	do	3	78	78
SUMMARY.							
Big Tarkio	Missouri	Missouri		Flour and grist	2	15	66
Tributaries	Big Tarkio	Missouri and Iowa		do	3	31	67
Little Tarkio	Missouri	Missouri		do	1	14	10
Nodaway	do	Missouri and Iowa		do	12	93	300
Tributaries	Nodaway	do		do	6	66	140
Platte	Missouri	do		Flour and grist (1 saw-mill)	14	122	530
One Hundred and Two	Platte	Missouri		Flour and grist	8	71	283
Small streams	do	do		do	1	9	50
West Grand	Grand	do		do	9	62	240
Small streams	West Grand	do		do	1	10	30
East Grand	Grand	do		do	5	38	135
Thompson's fork	East Grand	Missouri and Iowa		do	6	45	255
Weldon	Thompson's fork	do		do	3	20½	110
Medicine	Grand	Missouri		do	3	25½	50
Locust	do	do		do	6	53	170
Small streams	do	do		do	4	36	67
Chariton	Missouri	Missouri and Iowa		do	2	16	88
Mussel fork	Chariton	Missouri		Flour, grist, and saw	4	34	127
Small streams	do	do		do	2	18	50
Do	Missouri	do		Flour and grist	8	140½	169
Total					100	925½	2,958

IV.—TRIBUTARIES ON THE WEST SIDE OF THE MISSOURI RIVER, BELOW FORT RANDALL.

THE NIOBRARA RIVER.

Although my own visits to the tributaries which the Missouri receives from the west did not extend north of the Platte river, there are certain peculiar features of the Niobrara, described in published accounts, which lead me to make mention of it.

This river heads in the eastern part of Wyoming territory, 30 or 40 miles east of Fort Fetterman. From this point it takes a general easterly course, and enters the Missouri river near the town of Niobrara, in exactly the same latitude as that of its source, namely, 42° 47′ north. Its entire length, measured along the general line of its flow, is about 365 miles. For the last 55 miles of its course it forms the boundary between Nebraska and Dakota, which boundary is continued for 35 miles by the Keya Paha, a tributary of the Niobrara. It is not possible to fix accurately upon the water-shed lines, owing to the incompleteness of present maps, but the area drained is approximately 13,200 square miles. Of this 1,750 square miles belongs to the Keya Paha river, and 2,200 to the Snake, the most important affluents.

The finest description of the Niobrara is to be found in the *Preliminary Report of Explorations in Nebraska and Dakota, in the years* 1855–1857. This report was made by Lieutenant (now General) G. K. Warren, Corps of Engineers, who said concerning the river:

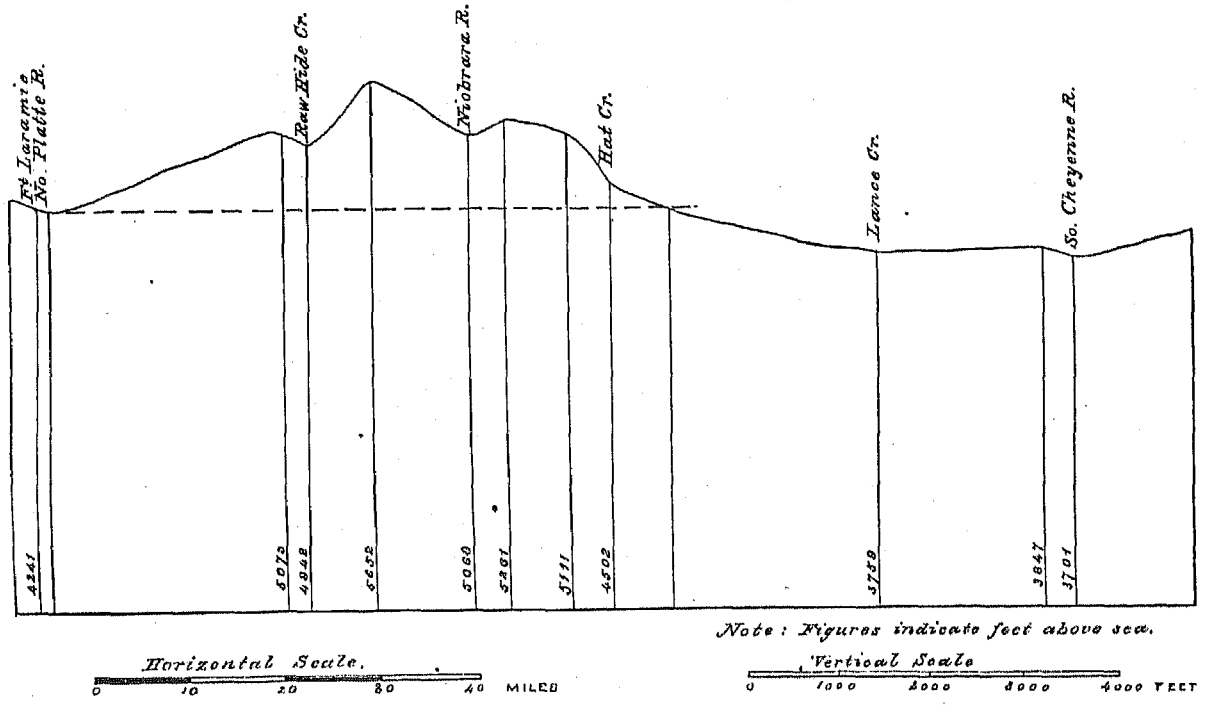
> From its source to longitude 103° 15′ it is a beautiful little stream of clear, running water, of a width of from 10 to 15 feet, gradually widening as it descends. Its valley furnishes here very good grass, abounding in rushes or prele, but is for the most part destitute of wood, even for cooking. After flowing thus far, it rapidly widens, till in longitude 102° 30′ it attains a width of 60 to 80 yards; its valley is still quite open and easy to travel along, but destitute of wood, except occasional pines on the distant hills to the north. In longitude 102° 30′ it enters between high, steep banks, which closely confine it, and for a long way it is a complete cañon; here, however, wood becomes more abundant, and pine is occasionally seen on the bluffs, while small clusters of cottonwood, elm, and ash occupy the narrow points left by its windings. In longitude 101° 45′ the sand-hills come, on the north side, close to the river, while on the south side they are at the distance of from 1 to 2 miles off, leaving a smooth road to travel on along the bluffs.
>
> The bluffs gradually appear higher and higher above the stream as it descends, until they reach the height of 300 feet. The sand mostly ceases, on the north side, in longitude 100° 23′; but it lies close to the stream on the south side, nearly all the way to Wazi-honska. Throughout this section, lying between longitude 102° and longitude 99° 20′, a distance of 180 miles, the Niobrara is in every respect a peculiar stream, and there is none that I know of with which it can be compared. It flows here between high rocky banks of soft white and yellowish calcareous and siliceous sandstone, standing often in precipices at the water's edge, its verticality being preserved by a capping of hard grit. As you approach from the north to the south, there are no indications of a river till you come within 2 or 3 miles of the banks, and then only by the trees, whose tops occasionally rise above the ravines in which they grow; so completely is it walled in by the high walls which inclose its narrow valley. It seems as if it had resulted from a fissure in the earth's crust, and now flows at a depth of about 300 feet below the general level of the prairie.
>
> The soft rock which forms the bluffs is worn into the most intricate labyrinths by the little streams, all of which have their sources in beautiful gushing springs of clear, cold water. In these small, deep valleys, the grass is luxuriant; pine, ash, and oak are abundant. From longitude 99° 20′ to the mouth, an extent of about 90 miles, the bottoms will probably average a width of a quarter of a mile, are susceptible of cultivation, and cottonwood, oak, walnut, and ash will furnish settlements with all the timber and fuel they will need. The river banks seem to present no good building stone, nor did we, though searching diligently, discover any signs of coal or other valuable minerals.
>
> The Niobrara is a very shallow and "swift-flowing stream", as the Canadians say, "*l'Eau qui Court,*" abounding in rapids in two-thirds of its upper course, and in its middle portion filled with small islands. In the lower portion its width exceeds that of the Missouri river, and is spread out over sand-bars. The bed in the broad portions is quicksand, and difficult to ford. Its waters rapidly increase in volume through its middle portion from the multitude of springs and streamlets that constantly flow into it from the foot of the bluffs and out of the ravines. The traders of the American Fur Company have navigated it with skin boats, carrying peltries from their former trading-house near Snake river, and the stream might permit of rafting if the timber should be found of quality, quantity, and accessibility to defray the expenses.

The Keya Paha, or Turtle Hill, river is the most important tributary on the north side of the Niobrara. It is about 120 miles long, and has a width of 50 yards at the mouth. The valley is one-half to three-quarters of a mile wide, with good soil and a limited quantity of cottonwood timber. The river bed is sandy, and the waters are clear and sweet.

Snake river, on the south side of the Niobrara, is some 30 yards wide toward the mouth, and has considerable pine timber along its bluffs. There are numerous other small streams entering the main river at various points, which are in general clear and swift-running; but owing to the peculiar formation of the Niobrara basin, there are, with the exception of the Keya Paha and Snake, no tributary streams of much length:

A peculiar feature of the main stream is the position it occupies upon a ridge. Regarding this subject Professor Aughey remarks in his *Sketches of the Physical Geography and Geology of Nebraska:*

A large part of the entire middle portion of the Niobrara river, as first observed by General Warren, flows lengthwise of an anticlinal ridge. In the cañons, for example, the rocks dip away from the river on each side. In places where I had opportunity to measure the angle, their inclination away from the stream amounted to from 10° to 15°. It is probable that the river has been outlined only since the close of the submergence that attended the Glacial age. Flowing along this anticlinal ridge, where it first emerged, it has continued in its old rut as the continent was rising, cutting down its bed about as rapidly as the uplifting took place. The cutting of the river still continues, though its rate is uncertain. As would be expected, the tributaries of the Niobrara that flow into it from the north or south are very short. The larger ones invariably flow parallel, or nearly parallel, to it. In the cañon region, in going to the Niobrara, when within 12 or 15 miles of it, I invariably found myself going up hill. When the river was reached, it lay from 150 to 400 feet below.



PROFILE ACROSS HEADWATERS OF NIOBRARA RIVER.

The phenomenon which has been described is plainly illustrated in the profiles accompanying certain reports by Captain W. S. Stanton, Corps of Engineers. Several of these profiles show the elevated position of the river, and from them I have selected one near the headwaters, where this feature is especially prominent.

The slope of the river is approximately shown in the following table:

Slope of Niobrara river.

Locality.	Elevation above sea.*	Fall between points.	Distance between points.†	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near source	5,069	487	42	11.60
Latitude 42° 34′, longitude 103° 57′	4,582	464	34	13.65
Latitude 42° 26′, longitude 103° 18′	4,118	1,428	130	10.98
Mouth of Snake river	2,690	730	97	7.53
Mouth of Keya Paha	1,960	720	52	13.85
Mouth of Niobrara	1,240			

* Authority for elevations: For the first three, Captain W. S. Stanton; for the last three, Professor Samuel Aughey.
† By map measurement, and probably much less than the true water distances.

South of the Niobrara, and toward the headwaters of the Loup and Elkhorn rivers, is a region containing many sand-hills. They are of a somewhat conical shape, varying in height from a few yards to several hundred feet; their sands are partially movable, and by the action of winds they have been carved into very curious forms. In the same region there are great numbers of small lakes, ponds, and sloughs; these are underlaid by an

impervious clayey stratum, so that the only escape for their waters is by overflow or evaporation. Some drain into the streams, but most have no visible outlet. In the section occupied by these lakes and sand-hills, the temperature often rises extremely high during the summer months, and thunder storms are of almost daily occurrence.

Judging from the records at Fort Randall and Fort Laramie, the rainfall over the basin of this river is about 5 inches in spring, 5½ in summer, 3 in autumn, 1½ in winter, and 15 inches for the year. I shall attempt no estimate of the low-water volume of the stream; the only record of any gauging of which I can learn is one furnished me by Professor Aughey, who measured the discharge in July, 1877, when the river was at a high stage, and found it to be 15,760 cubic feet per second at the mouth, or at the rate of 1.19 cubic feet per second per square mile of drainage area.

Steel creek, in Knox county, a tributary of the Niobrara, has one small grist-mill, using 20 horse-power, but the main river is wholly unemployed. It lies in a very sparsely settled region, the combined population of the three counties of Knox, Holt, and Sioux, which adjoin it on the south, being but about 7,700. The basin of the river is at present entirely without railroads; a branch of the Chicago, Milwaukee and Saint Paul road, in southeastern Dakota, extends to a point on the Missouri nearly opposite the mouth, and the Sioux City and Pacific Railroad Company has two lines following up, respectively, the main Elkhorn and its north branch, and approaching within about 20 miles of the Niobrara on the south; these may in time be prolonged to the course of that river.

THE PLATTE RIVER.

So far as regards extent of area drained, the Platte is the most important tributary of the Missouri. It is formed by two forks, the North Platte and the South Platte, which rise, respectively, in northern and in central Colorado, and unite somewhat southwest of the center of Nebraska. From the point of junction the main river pursues a winding course to the east across the state, and empties into the Missouri river at Plattsmouth; its length between these points is, by general course, 285 miles. Its entire drainage basin comprises about 90,000 square miles, of which, in round numbers, 36,000 belongs to the North Platte and 24,000 to the South Platte. The lower course of the river is through a section fairly well settled, but advancing westward the population becomes more scattered, and beyond Fort Kearney few places of importance are found off the line of the Union Pacific railroad, which follows the valley from near the mouth to North Platte and then continues along the course of the South Platte river. Plattsmouth, at the mouth, has a population of 4,175; and above this the larger places along the river are Fremont, Schuyler, Columbus, Grand Island, Kearney Junction, and North Platte, containing from 1,000 to 3,000 inhabitants each. According to the statistics of Mr. Gannett, the population of the entire basin of the Platte has increased from about 69,000 in 1870 to 265,000 in 1880.

The course of the river lies through a broad and level bottom, rather sandy in places, but, on the whole, fertile and well suited to the raising of corn, wheat, potatoes, and grass. The rainfall is somewhat deficient and uncertain, however, and partial failures of crops from that cause are not uncommon. The bottom-land is bordered by bluffs, probably varying from 50 to 300 or 400 feet in height; at some points there is a gradual ascent to their summits from the river, while at others they rise more abruptly. The valley inclosed by them varies considerably in width, but in the vicinity of the mouth of the Loup ranges from 3 to 8 miles across. The river occasionally runs close to the bluffs, but usually maintains its position well out in the bottom.

The Platte is a broad and shallow stream; at Central City it is three-quarters of a mile to a mile wide, and for 100 miles above Columbus the width between banks is estimated to average half a mile. The width of running water, however, in that section, is much less at an ordinary stage; the main channel is not more than 150 feet wide and 2 to 3 feet deep, while over the remaining width there are pools and little rivulets interspersed among sand bars. Opposite the town of Grand Island the river divides into two main channel-ways, each about 2,100 feet across, and numerous minor channels of small width; in order to cross the entire stream at this point the county of Hall was obliged to build nine separate bridges, spanning these different divisions of the main river. The banks are generally sandy and low, averaging not more than 3 feet in height. The bed is of quicksand and very shifting; a person may easily ford the stream with a team at one hour, but on returning in a short time will find, if there has been meanwhile a change in the wind, as from north to south, the channel forced to the north shore, and his team will sink at every step. When roiled from any cause, the water becomes yellowish in color and is very opaque.

The Platte has a rapid descent and a swift current. The elevations in the accompanying table are by railroad surveys, and do not correspond exactly to the water surface; still they will give a very good idea of the general slope.

Elevations on the Platte river.

[From *Physical Geography and Geology of Nebraska.*]

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
North Platte†	2,825	410	63	6.05
Plum creek†	2,406	263	34	7.74
Kearney†	2,143	420	66	6.36
Central City†	1,723	351	55	6.38
Schuyler†	1,372	437	86	5.08
Plattsmouth ‡	§935			

*Map measurement along river's course.
†Elevation of rails, Union Pacific railway.
‡Elevation of rails, Burlington and Missouri River railroad.
§Furnished by T. E. Calvert, esq., chief engineer.

The principal freshet in this river occurs in June, and is due to the melting of snow at its headwaters in the Rocky mountains, and the heavy rains of late spring and early summer. Although the banks are very low and the freshet volume is large, still the width and slope are such that the stream seldom overflows to an important extent; even in high water the depth in the vicinity of Grand Island only ranges from 2 to 6 feet. Following the June rise the volume rapidly diminishes, and the river at length either disappears entirely in its sandy bed or becomes reduced to a chain of pools. It may be lost to sight for some distance, and then appear again where forced up by the position of the underlying strata. Mr. W. W. Watson, civil engineer, of Fairbury, Nebraska, stated that he had traveled along the Platte and found it dry for 300 miles above the mouth of the Loup. Although the river sinks away in the sand, its waters are yet leaching along through the bed, but, of course, with a very slight current; the current, can, however, be perceived if a trench be dug 3 or 4 feet deep, at which depth water will always be found. The phenomenon which has been described is claimed to have become more marked during the past few years, owing to the increased use of the waters of the South Platte for irrigation in Colorado.

Since a large volume of water is thus lost to sight, the question naturally arises, What becomes of it? A portion of it probably leaches along in the manner already spoken of, and either is brought to the surface of the river bed again, or else continues its flow underground along the general course of the stream, at length finding its way into the Missouri. But another portion, doubtless much the greater, escapes by underground drainage to the south into the Republican and Blue rivers. The general slope of the surface of Nebraska is to the east, but in the southeastern portion of the state the slope becomes southeast. In that section the Platte receives hardly a tributary of any length from the south, except Salt creek, which empties 25 or 30 miles from the mouth; much of the way the southern water-shed is but 2 or 3 miles from the stream, and for two-thirds of the distance from North Platte to the mouth it is not, on the average, more than 10 miles from its course; the same feature continues to a greater or less degree along the South Platte into Colorado. The southeastern part of Nebraska is mainly covered by the Loess or Bluff deposit, underlaid by the sand, gravel, and clay of the Drift; the surface materials and prevailing slope are thus seen to be favorable to underground drainage, and the proofs of its actual occurrence are numerous and convincing.

Even when the river is at a fair stage, Professor Aughey has discovered that the volume diminishes largely between North Platte and the mouth. Thus, as the mean of five determinations, he found the discharge at the mouth to be 18,354 cubic feet per second, "at the close of the June flood, after the waters had assumed the level they had previous to that rise"; two days later, having in the meantime proceeded to the junction of the North and South Platte, he measured a discharge of 22,953 cubic feet per second in the main stream at the latter point. These measurements show, not a gain, but an actual loss in volume of 4,600 cubic feet per second between North Platte and the mouth; this loss cannot be due to evaporation, for the Loup and the Elkhorn add much more to the volume than it is at all probable could be lost in that manner. This is not necessarily a proof that the water lost passes into the rivers to the south; but it is to the point, however, that the Republican and the Blue, although neither of them reaches to the mountains or has a large snowfall over its basin, answer promptly to a rise in the Platte by an increase in their own volume, whether that stream is swollen from melting snows in the Rocky mountains or from any other cause.

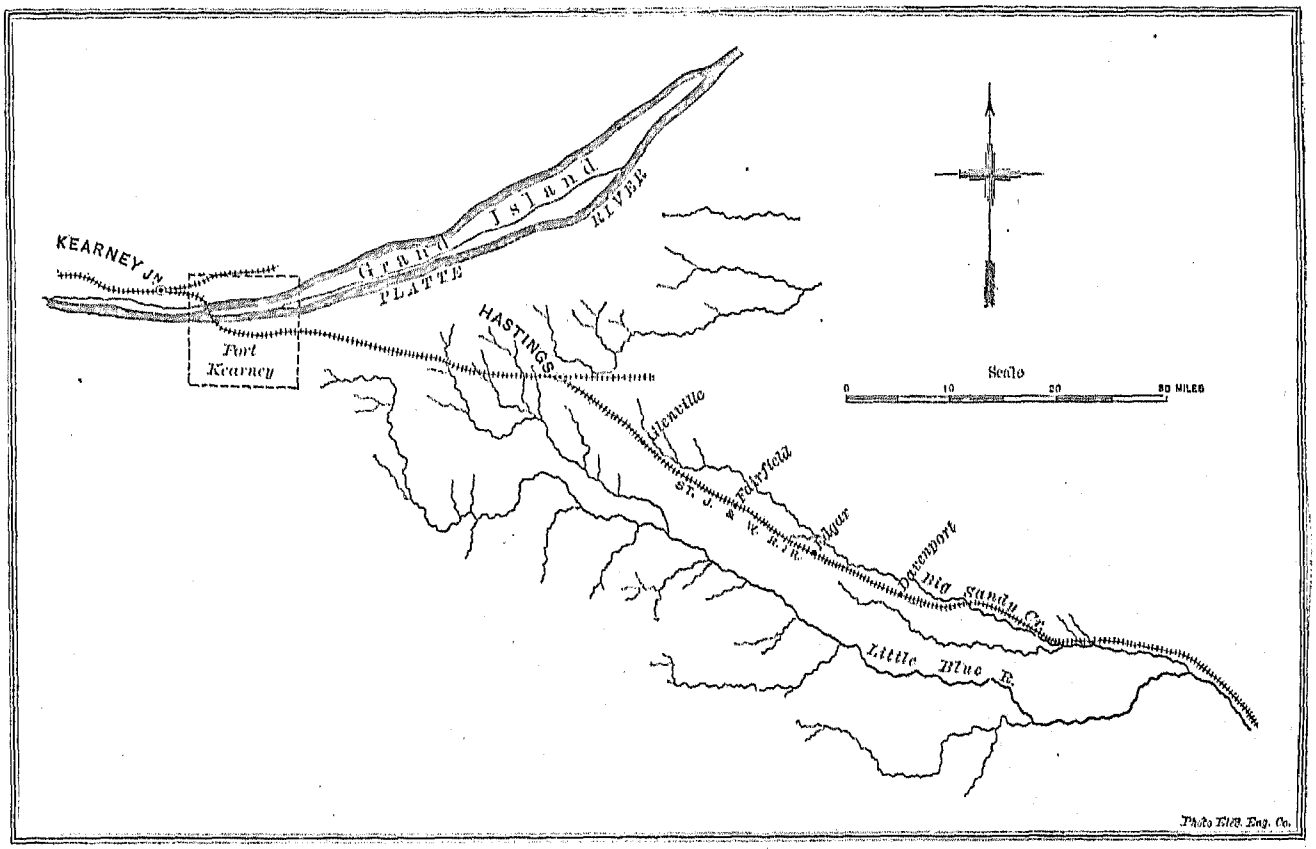
Regarding the phenomenon of underground drainage, Professor Aughey says:

The average volume of water at North Platte is greater than at the mouth, though it receives in the mean time some large tributaries, the most important of which are the Elkhorn, Papillion, Shell creek, Loup, and Wood river. A few hold that this was caused by evaporation. The tributaries, however, that enter the Platte from the north more than supply the waste from this cause. The explanation of this phenomenon is found in the character of the bottom, and its continuation with the Drift under the Loess as far as to the Republican. It will also be seen in the lists of elevations that have been given that the general level of the Republican is 352 feet below that of the Platte. There is therefore a descent from the Platte to the Republican, and along such a formation that there is easy

drainage from the one into the other. That there is such a drainage upon an extensive scale I have no doubt. Wading in the Republican in August, as I have done for many miles at a time, I noticed on the north side water oozing out of the Drift continuously every few feet in places, and rarely at greater intervals than every few rods. Nothing of the kind was noticed on its southern shore. Where tributaries of the Republican from the northwest cut deep enough to strike the Drift they share in the reception of this water from the Platte. Few, however, do this.

This escape of the drainage water through the river banks, observed on the Republican by Professor Aughey, has also been noticed on the Big Blue in the vicinity of Beatrice, and very likely at other points; in the former locality it is said that it can frequently be seen issuing in a thin sheet from the banks.

A striking proof of this flow southward from the Platte is afforded by the profile and borings along the line of the Saint Joseph and Western (*a*) railroad. This road, passing southeasterly from Hastings, follows down the valley of Big Sandy creek till that stream unites with the Little Blue. Along the railroad wells were sunk at various points in order to obtain water for supply-tanks. An accompanying map shows the geography of this section,



MAP ILLUSTRATING DRAINAGE FROM THE PLATTE RIVER.

while in another cut are illustrated the profile of the road and the positions of the wells. The profile was furnished me by Mr. W. W. Watson, of Fairbury, who also supplied the following extract from an article by Mr. E. Whiting, formerly chief engineer of the Saint Joseph and Denver railroad, which fully explains the proof supplied by the profile:

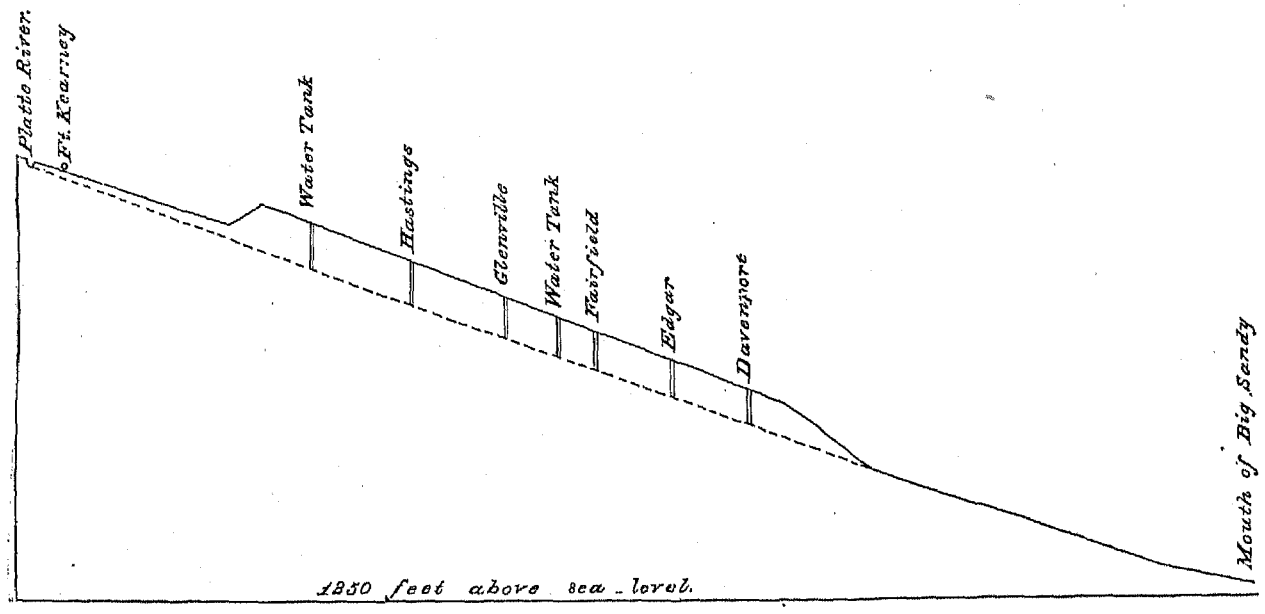
The Big Sandy at its mouth is a stream 30 to 40 feet wide, ordinarily 2 to 4 feet deep, running with a swift current, the fall being from 6 to 10 feet per mile; the water is very clear, pure, and soft. This volume is maintained even in dry seasons, and for a distance of 8 or 10 miles up the stream, excepting only in cases of melting snow or heavy rains at or near its head; at such times the river rises suddenly, the water becomes turbid and muddy, receding almost as quickly as it came up, after the cause of its rise has abated. About 15 miles from its mouth the water ceases entirely to run (except in case of floods), standing only in pools. Between its mouth and where it ceases to flow it receives no tributaries of running water, and but few springs are visible.

The ridge or plateau traversed by the railroad, between the Big Sandy and the Little Blue, is apparently very flat or level, having a gradual rise to the northwest of about 8 feet per mile. At the stations of Davenport, Edgar, Fairfield, Glenville, and Hastings wells were bored; also wells were dug to supply a tank between Fairfield and Glenville, as also beyond Hastings. At depths, shown on the profile, varying from 108 to 112 feet, water in great abundance was found, clear, cold, and pure, similar to the water in the Big Sandy. By looking at the profile it will be seen that a line drawn through the bottom of these wells would be in almost a straight line, falling to the southeast about 8 feet per mile, or the same as the surface of the ridge. If this line be continued, with the same inclination, eastwardly from Davenport, it would strike the bed of the Big Sandy at about the same point where the water begins to flow permanently in that stream. The same line, continued northwesterly, would correspond to the bed of the Platte near Fort Kearney. The bed of the Sandy is composed of the same kind of sand, gravel, and pebbles as that found at the bottom of the wells on the ridge. Similar sand and gravel compose the bed of the Platte.

a Formerly Saint Joseph and Denver.

Whatever ice forms in the Platte is said usually to waste away before breaking up. The river has absolutely no value for navigation; no rafting is done, and only a slight fringe of timber is found upon the banks. The only use, in fact, to which the main river is put is to furnish power to a few flouring- and grist-mills of moderate size, mainly located in Merrick county. The damming of the stream in the ordinary manner is evidently impracticable, and the method adopted at these mills is to divert sufficient water into the races by some rude means, as, for instance, a short wing-dam of brush. The races run between embankments of earth thrown up on either side, and

[Compiled from report of E. Whiting, formerly chief engineer Saint Joseph and Denver railroad, by W. W. Watson, Fairbury, Nebraska. Vertical scale, 400 feet to 1 inch. Horizontal scale, 20 miles to 1 inch.]



PROFILE OF SAINT JOSEPH AND WESTERN RAILROAD, FROM LITTLE BLUE RIVER TO KEARNEY JUNCTION, ON PLATTE RIVER.

are gradually raised above the level of the river, to which they run approximately parallel. Unless favorable sloughs can be found, across which dams might be thrown, and which would serve at once as head-race and tail-race, this seems to be the only method of employing the Platte for power. The construction of the races by embankment is claimed not to be especially expensive, and the water is held successfully; yet there are certain disadvantages, for considerable sand is deposited in them, and they become thickly frozen over in very cold weather, and in summer and autumn there is a scant supply of water.

TRIBUTARIES OF THE PLATTE.

In describing the tributaries I shall take up the more important ones in order from the mouth of the Platte.

The first to be noticed is Salt creek, a small stream joining the Platte from the south at Ashland, and draining, principally, the counties of Lancaster and Saunders. It has a length of perhaps 45 miles by general course, and drains 1,630 square miles. A line of the Burlington and Missouri River railroad follows the creek to its mouth from Lincoln, capital of the state, and the most important town on its course.

The creek receives its name from the salt springs and salt marshes found near its upper waters. Elevations on the railroad show a descent of 62 feet from Lincoln to Ashland, but the actual fall in the water surface of the stream I am unable to give. In an ordinary stage of water the width near the mouth is 75 feet, and there is a current of 3 or 4 miles an hour. The stream is very crooked, but never overflows its banks.

The lowest mill on the stream is at Ashland, near the mouth, where power is employed by a four-run flouring-mill, having a head of 7 feet and using 40 horse-power; about 8 horse-power is also in use by a small wind-mill factory at the opposite end of the dam. There is an abundance of water for these establishments throughout the year, and a considerable surplus also; for two weeks more or less trouble is experienced with backwater from the Platte. The dam was built in 1864, and is a framed structure resting upon and bolted to a bed of limestone. It is 240 feet long, 7 feet high, and is claimed to set back the river 11 miles by land, or 33 miles by water, thus forming a pond having an average width of 60 feet.

Some 7 miles above Ashland Rock creek empties in from the west. It is a small stream, and is said to have one mill of two runs and another of one run. On the main stream there is a mill at Waverly, one of four runs and one of two runs at Lincoln, and one of two runs at Roca. The dams are usually of brush, and range from 50 to 75 feet in length, with a height of 10 or 12 feet. Bragg's mill, at Lincoln, has four runs of stone, and uses a 34-inch Leffel

wheel running under a head of 11 feet. The dam is 50 to 60 feet long, 11 feet high, and was built in 1880 at a cost of $350. It was constructed of brush in the usual manner, except that the successive layers were secured by lines of stakes running across the stream and having stout withes interwoven among them.

The bed of the stream is sandy or muddy, and the banks are of loam, 10 to 20 feet high. The flow is quite steady and adapts the stream very well to milling purposes; but the fall is slight, and it is thought there is not much available power unused in the more important part of its course.

THE ELKHORN RIVER.

The Elkhorn rises in northern Nebraska, and taking a southeasterly direction empties into the Platte about 30 miles above its mouth. Its principal tributaries are the North Branch, and Maple and Logan creeks. The length, by general course, is 215 miles, and the entire area drained 6,732 square miles. The greater part of this section is sparsely settled, but is increasing in population with the extension of railroad facilities; the counties directly bordering the main river have a combined population of about 82,000. West Point is the largest place on the river, and has about 1,000 inhabitants. The Sioux City and Pacific railroad follows up the Elkhorn from its lower course nearly to the headwaters, and a branch of the same road also ascends the valley of the North Branch.

The Elkhorn has its source in a large tract of marshy land; thence it flows through a rolling prairie country, fertile and well adapted to the raising of corn, but possessing very little timber. It is bordered immediately by bottom-land 1 mile to 3 miles wide, beyond which there is a gradual rise to the upland. From West Point to the mouth the average width between banks gradually increases from 150 to 170 feet. The actual water-way measures less than this, however, in an ordinary stage, and is not more than 115 feet wide in the lower course. The banks are of loam, and have a height of 6 or 8 feet; the bed is sandy, and frequently quicksand. The river is very winding, but has a swift current. Considerable snow falls, toward the headwaters, and drifts deeply in the gulches; about the first of May the melting of this snow causes a freshet, which is assisted by heavy rains; the Elkhorn then runs with full banks, but only once in four or five years does it overflow to a noteworthy extent.

Elevations and slope of Elkhorn river.

[Supplied by Mr. E. Gerber, assistant engineer Sioux City and Pacific railroad. On the profile of the road elevations are referred to the level of Lake Michigan, which is assumed at 581.92 feet above mean tide at New York. See *Report Chief of Engineers*, 1878, page 1409.]

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Near O'Neill†	1,060			
		190	36	5.28
Near Antelope†	1,770			
		57	16	3.56
Near Oakdale†	1,713			
		167	27	6.19
Near Marietta†	1,546			
		271	73	3.71
Near Crowell†	1,275			
		106	36	2.94
Near Bell creek†	1,169			
		67	13	5.15
Waterloo‡	1,102			

*Map measurement.
† Water surface at Sioux City and Pacific railroad crossing.
‡ Water surface at Union Pacific railway crossing.

Only a very small amount of power is in use on the Elkhorn, partly on account of a lack of demand, and partly from the difficulty of maintaining dams. The sandy nature of the bed is certainly an objection, but brush dams are in successful use on similar streams elsewhere, and would doubtless answer their purpose equally well here. There are no abrupt falls and no rapids of any importance, so far as I can learn; but I was informed by a mill-owner who was well acquainted with the river, that once in 4 miles, on the average, an available site could be found where a head of 6 to 8 feet might be secured. The river being very crooked, as stated, it is considered that a fair amount of fall might be obtained at favorable points by running a race across the neck of a long bend.

The few powers which are utilized on the Elkhorn will be given in a subsequent table. The only important development of this stream for water-power is at West Point, at a privilege owned by Mr. John Neligh. At the time of my visit, in December, 1880, about 225 horse-power was employed by a grist- and flouring-mill, a paper-mill, planing-mill, and an establishment for the manufacture of condensed milk. The dam was built in 1867, and is estimated to have cost $7,000. It is 200 feet long, 8 feet high, and is constructed of brush. The quicksand bed on which it rests allows a gradual sinking, and renders necessary an annual outlay of about $1,000 for repairs. A long embankment, running from one end of the dam proper, serves to inclose the river on that side. On the opposite side of the river the bank below the dam is protected from washing by a thick layer of brush and sod. The head on the wheels is about 9 feet. The mills located at this privilege have abundance of water for running at full capacity throughout the year. They are not troubled to a serious extent by ice, nor for more than one week in the year by backwater. The river is said to have a very steady flow, running lowest in winter.

At Neligh, in Antelope county, there is also a four-run flouring-mill, using about 66 horse-power, with a head of 8 feet.

Of the tributaries of the Elkhorn, Logan creek is a good mill stream and probably presents numerous unoccupied sites. It averages 25 to 30 feet in width between banks, and is of fair depth, with a steady supply of water. Maple creek, which joins the Elkhorn from the west not a great way below Logan creek, is of about the same size as the latter, and has one mill. The north branch of the Elkhorn lies mainly in Pierce county and has one mill; the Sioux City and Pacific railroad, which follows its course, descends 63 feet between Pierce and Norfolk, indicating a probable average fall for the river of about 4.5 feet per mile.

SHELL CREEK.

This stream, the next tributary of the Platte above the Elkhorn, comes from the northwest and is about 60 miles long by general course. For 20 miles above its mouth it averages 40 feet in width and 18 inches in depth in an ordinary stage; on its course there are four or five flouring-mills, which obtain heads of 10 to 18 feet, and carry from two to four runs of stone each. According to the levels of the Union Pacific railway, the fall in the water surface from Platte Center to Schuyler is 211 feet, or an average of 7.5 feet per mile.

THE LOUP RIVER.

Two principal forks, rising in northwestern Nebraska, pursue a southeasterly course and unite in Howard county to form the main Loup river; the latter runs easterly and empties into the Platte in the southeastern corner of Platte county. From the source of the Middle Loup the distance, by general course, to the Platte is 260 miles. The Loup drains a total area of 15,553 square miles, having a rolling prairie surface. For 150 miles above the mouth farming land of fair value is found along the bottoms, but farther west it becomes too sandy, especially on the uplands, to be of much worth. No timber of importance occurs along the Loup or its main branches, but on the courses of some of the small tributaries a moderate amount of hard-wood timber grows.

For 30 miles above the Platte the bottom-land averages 4 miles in width, and for 70 miles ranges between 2 and 4 miles. In the lower course the river itself is 300 to 400 yards wide between banks. In an ordinary stage the channel is confined to a width of 50 yards, in which the depth is 4 to 5 feet, while for the remaining distance the depth is 6 inches to 2 feet. The banks are of sandy loam, and range from 2 to 6 feet in height. The bed is of quicksand, a material which seems to underlie the whole surrounding region, and which stretches out in a uniform plane. In the bottoms it is spread out only a short distance beneath the surface. It appears to be considerably stratified, layers of fine quicksand occurring alternately with layers of coarse sand which is almost a gravel. Sixty or 70 miles above the mouth an occasional ledge of rock is encountered in the river bed.

Not enough snow falls at the headwaters to cause an annual freshet such as characterizes the Platte and the Missouri, and it is only after a severe and protracted storm that there is a heavy rise. The banks are seldom overflowed unless there is heavy ice running and a gorge is formed; but this has been known to happen only once in fifteen years on the lower river.

There are no dams on the main stream, and it is not used in any manner for power. Its width, and the treacherous nature of its bed, prevent improvement by dams extending across the river; but by the construction of short wing-dams, sufficient water might probably be diverted into races to be run either between dikes or along high ground, where the latter is near at hand. The flow of the stream is steady, its current good, and its course generally quite straight.

Elevations on Loup river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Head of Middle Loup†	3,230	1,459	195	7.48
Saint Paul‡	1,771			
Columbus‡	1,434	337	62	5.44

* Map measurement.
† Barometric measurement by Professor Aughey.
‡ Water surface at Union Pacific railway crossing.

TRIBUTARIES OF THE LOUP.—These nearly all flow from the northwest. Beaver creek, the first of importance in ascending the stream, empties 18 miles west of Columbus. In an ordinary stage it is 50 yards wide at the mouth, and 2 feet deep; its bed is generally muddy. Cedar creek is 80 miles long by general course, and in its lower portion averages 200 feet in width; its bed is sandy. No power was in use at the time of my visit, though a large mill was being built.

The North Loup is 195 miles long by general course. Its lower valley is of moderate fertility, but above Ord the country away from the river becomes quite sandy. Near the mouth the width between banks averages 400 to 500 feet; in some places the stream spreads over this entire distance, but in others it is confined to half the width or even less. Where running the full width, the mean depth is perhaps 2 feet in an ordinary stage. Above range 30 there are said to be several abrupt falls of 4 to 6 feet each, over shelves of clay; in one locality, no less than four of these occur in 3 miles.

The Middle Loup rises 15 or 20 miles south of the source of the North Loup, and runs approximately parallel to that stream. About 20 miles above their junction it is joined by the South Loup, an important tributary. There is a small grist-mill at Saint Paul, but no other power is used on either of these rivers. The South Loup (*a*) is 100 to 150 feet wide and 2 to 3 feet deep. It formerly had more timber than either of the other streams just described, but this has been largely cut away. In township 18, range 26, there is a sudden fall of about 4 feet over a clay shelf.

The North, South, and Middle Loup are all characterized by a bed usually composed of quicksand, and banks of sandy loam 3 to 5 feet high. They have a swift current, rapid descent (7 or 8 feet per mile), and being fed to a considerable extent by springs, have a well-sustained flow. I was informed that at Ord and at Saint Paul, where power is used by flouring-mills of four and two runs, respectively, the streams are not completely dammed, but some simple device is employed to divert water into canals, which are run far enough to gain the desired head.

The streams to which I have referred are free from serious freshets, except as resulting from severe and long-continued storms; even then they seldom overflow their banks. A foot to a foot and a half of snow falls during December, but commonly wastes away by the middle of January, and has no important effect in raising the streams. These bring down considerable floating ice in the spring, and upon a sudden breaking up it is liable to form a gorge in some bend or narrow, or upon an extensive sand-bar.

The basin of the Loup is very sparsely settled. Columbus, near the mouth of the main river, has about 2,100 inhabitants, but with this exception the largest town is Saint Paul, which has a population of not over 500. A branch of the Union Pacific railway follows the lower river for about 10 miles, and another branch extends from Grand Island to Saint Paul; but neither the Loup nor its principal branches are touched by railroads at any other points.

THE NORTH PLATTE RIVER.

This important stream is formed in northern Colorado. It makes a bold curve to the northward into Wyoming, and then assumes a southeasterly direction, which it maintains to its junction with the South Platte, in Nebraska. Its length by general course is 540 miles; the area drained is approximately 35,574 square miles, of which 2,055 are in Colorado, 25,268 in Wyoming, and 8,251 in Nebraska. The slope of the river is shown in the accompanying table:

Elevations and slope of the North Platte river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
North Park, Colorado†	7,000			
		1,125	100	11.36
Fort Steele, Wyoming§	6,475			
		1,636	137	11.04
Point on left bank, near Fort Fetterman.‖	4,839			
		630	69	9.13
Fort Laramie‖	4,209			
		1,445	209	6.91
North Platte§	2,764			

* Map measurement.
† Average elevation of park, as given by Arnold Hague.
‡ From mouth Cheyenne creek.
§ Water surface at Union Pacific railway crossing.
‖ Elevations as given by Captain W. S. Stanton.

The source of this river is in North Park, or rather in the mountains which hem it in on all sides, and which rise 4,500 to 5,000 feet above its general level. The Park is about 35 miles long in a north-and-south direction. In its connection with the Platte it is thus described by Arnold Hague: (*b*)

An undulating surface characterizes the North Park, yet changes in level are so gradual that a greater part of the area, when seen from any elevation that overlooks the basin, appears essentially a plain, only one or two points rising more than a few hundred feet above the Platte bottom. * * * The drainage system of the North Park forms one of its most striking physical features, the entire waters finding their outlet through one stream, the North Platte, whose sources lie high up in the surrounding mountains. Numerous small streams descend from all the steep slopes, which, uniting below into large creeks, flow out toward the center of the basin and make the three main streams, the East, the Middle, and the West Forks, which, at the extreme northern end, come together, forming the North Platte, already a very considerable river, where it breaks through the Archæan wall of the Park.

a Also known as Beaver creek, near the mouth.

b Report by Clarence King on *Exploration of the Fortieth Parallel.*

From North Park the river escapes through a cañon some 20 miles long, in which there is a swift current, with many rapids and falls. After leaving this cañon, its course lies through bottom-land averaging a mile in width, beyond which the country rises into rolling uplands, succeeded by low mountains. Below Fort Steele it is said to run for 16 miles through alkali flats, and then through a rolling, sandy country, till it reaches the Seminoe range, which it pierces, running in a very narrow cañon with numerous rapids and falls. Near the mouth of Deer creek, which empties about 20 miles above Fort Fetterman, there is reported to be an abrupt fall of 50 to 100 feet.

Between the upper cañon and the alkali flats the stream runs through a fine grazing region. It is said that much of the country in this part of Wyoming might be converted into good wheat lands by irrigation, but no important improvements of that kind have yet been introduced. From the upper to the lower cañon the bed and banks are of gravel, and the water is so clear that the bottom may easily be seen, except during high water, when the stream becomes very muddy; the banks are low, averaging not more than 4 or 5 feet in height. The current is very swift, being estimated at 7 or 8 miles an hour, and the flow is comparatively steady from month to month. The average low-water width is about 50 feet, and the depth 1 foot; in high water the river is 200 feet wide and 4 feet deep.

The North Platte runs lowest in winter, when it freezes thickly; as soon as the first spring rise comes, the ice breaks up and runs out. High water prevails from the middle of April till the middle of July; during this period the stream runs bank full, but never overflows to an important extent.

No power is employed upon the main river or upon any of its tributaries, and there will be little demand for such use of the stream for some time to come. If the Platte were to be used, the method of races formed by embankment would probably be found most practicable for improvements, on account of the low banks and the wide bottoms bordering the river. Some of the side streams which head in the mountains are said to be quite well sustained in flow, have clear waters, firm beds, and a rapid fall, ranging from 10 to 15 feet per mile and upward. The slope increases as their sources in the mountains are approached. Jack creek, which is only about 20 miles long in a straight line, falls 1,500 feet between its source and mouth.

Many of the small streams in this section are, however, declared to have no value for power. They carry but a small volume of water in a low stage, often sink away in the sand in their lower courses, and, where they have cut their channels down and formed deep gorges, frequently run through them with very sluggish current.

The Sweetwater, which is represented on the maps as a stream 130 miles long by general course, is said to be quite insignificant in a low stage, running scarcely more than 5 or 10 feet wide and 1 foot deep.

There is no timber worth mentioning along the North Platte from its source to Fort Fetterman. From the latter point to Fort Laramie the fall, as determined by barometric measurement, is 630 feet. (*a*) The width at Fort Laramie is 400 feet, and the depth at low water 3½ feet; the mean range between high and low water is 8 feet. The bed in that locality is composed of clay and bowlders, overlaid by a thin stratum of sand. The banks are of loam, and are firm. Above Fort Laramie the country along the course of the river is rough and broken. Captain Stanton informed me that, while constructing a bridge at the fort, the river above was reported by lumbermen to be so full of rapids and falls that logs could not be floated down without breaking them badly.

In its lower course the North Platte averages somewhat more than half a mile in width; the depth ranges from 1 to 10 or 15 feet in an ordinary stage, and has a mean of 1 or 2 feet. The fall is rapid, and the current, in consequence, swift; the volume is comparatively well sustained. Rain-storms produce no important effect, but the melting of snow in the mountains brings an annual June rise of about 2 feet. Whatever ice is found in this part of the river usually forms in December, and melts away during January. The river bed is composed of fine quicksand; when driven across this seems firm and hard, but if a team is halted it begins to sink and soon becomes locked in the sand. At a depth of 15 or 20 feet a hard layer is encountered which affords an excellent bearing for piles, and which seems to be a clay. The banks are alluvial, average 4 to 5 feet in height, and are never overflowed. Above the junction with the South Platte the bottom-land bordering the stream has a mean width of 5 or 6 miles; for about 20 miles up stream it is cultivated somewhat, and even beyond that distance has value as grass land; but in the latter section the soil is too dry, unless irrigated, for raising most crops, and is devoid of timber.

The valley and basin of the North Platte have but a very sparse population. Forts Steele, Fetterman, and Laramie are the only important points on the upper river; and on the lower course North Platte is the only place of any prominence. The only railroad in this section is the Union Pacific, which crosses the river near its mouth and then follows up the South Platte; it crosses the North Platte again at Fort Steele, Wyoming, but in the intervening distance is most of the way 40 to 80 miles from its course.

The average rainfall on the upper and more important portion of the drainage basin is approximately 4.3 inches in spring, 4.2 in summer, 2.7 in autumn, and 2.5 in winter; making a total of 13.7 inches for the year.

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a For my information concerning this part of the river I am indebted to Captain W. S. Stanton, Corps of Engineers, United States Army.

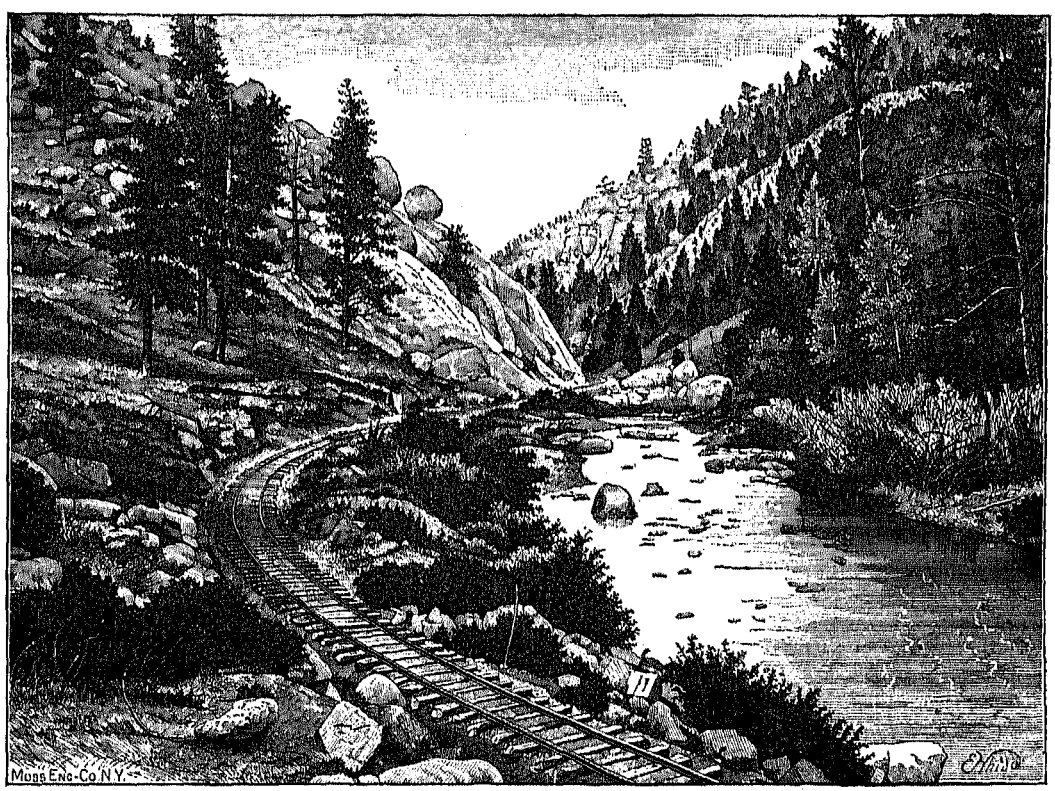
THE SOUTH PLATTE RIVER.

This river has its sources in the central part of Colorado; what is known as the Middle Fork starts from Mount Lincoln, 70 miles southwest of Denver. This locality is of interest as being an initial point of three great drainage systems: the Platte starts to the eastward on its long journey to the Missouri; the Arkansas, taking a course much farther to the south, passes on to the Mississippi; while, flowing to the westward, Eagle river empties into the Grand, which, farther on, merges in the Colorado, and so at length finds its way to the Gulf of California.

From Mount Lincoln the South Platte pursues quite a direct course to the southeast for about 45 miles; it then turns sharply, through more than 90°, and runs northeasterly for 125 miles without deviating 10 miles from an air-line. A short distance beyond Greeley it changes its direction to easterly and follows a more winding course, passing out of Colorado at the northeastern corner of the state, and uniting with the North Platte, in Nebraska, to make up the main river. It has a length by general course of about 400 miles, and a drainage area of 24,468 square miles, comprising 19,292 square miles in Colorado, 1,913 in Wyoming, and 3,263 in Nebraska. The country bordering the whole lower course of the river is very sparsely populated, and on account of the sandy soil and slight rainfall has little or no value for agriculture. Approaching the Rocky mountains, however, numerous streams are met with, mainly those heading in the mountains, which by their steady flow and rapid descent are well suited to use for irrigation; by employing these streams a tract of country 20 to 30 miles wide, running parallel to the base of the mountains and lying principally to the west of the Platte, has been made susceptible of cultivation, and yields large crops of grain.

Above North Platte the only prominent places on the river are Greeley and Denver. The Union Pacific railway follows the valley from the mouth to Julesburg, about 90 miles; it then passes up the valley of Lodge Pole creek into Wyoming; from Cheyenne two routes lead southward to Denver, the easterly one running for about 50 miles near the river; both these roads are owned by the Union Pacific company, which also has a line running up the valley of Clear creek, and another, the Denver, South Park, and Pacific, following the Platte for 25 miles above Denver and then turning up the course of the North Fork. From Julesburg to Greeley, a distance of 140 miles by general course, the river is not approached by any railroad line.

Near the head of the Middle Fork numerous little mountain streams are received, which are important only in spring, running very low at other seasons. Regarding the main portions of the Middle Fork and South Fork I



VIEW NEAR BUFFALO, ON THE DENVER, SOUTH PARK, AND PACIFIC RAILROAD.

have no data, but the general features of those streams can be sufficiently well determined from a description of the North Fork. The latter runs easterly, and is 35 or 40 miles long, by general course. Nearly its entire passage is among the mountains, which are heavily timbered with pine and spruce, and abound in mineral resources, including gold, silver, copper and lead. The fall is very rapid, and, as shown by the levels of the Denver, South Park, and

Pacific railroad, frequently amounts to more than 150 feet in a mile; this descent is in a series of rapids and is without abrupt falls of any consequence. With so great a slope the stream is, of course, a torrent in character. Its bed is rocky and contains many huge bowlders; it varies considerably in width, and ranges, I should say, between 25 and 150 feet. In places its valley widens out somewhat, but usually it is very narrow, being a succession of cañons, the sides of which rise, almost vertically at times, hundreds and even thousands of feet from the water.

There are no mills on this fork, but power could doubtless be used to good advantage, if there were any demand, at points where the valley is sufficiently wide. It is possible to obtain a very large head, and the stream has this advantage in the mountains, that it is not drawn upon for irrigation. There is no danger from ordinary freshets, but occasionally a sudden and heavy fall of rain, called a "cloud-burst", occurs and occasions damage.

Slope of the North Fork and South Platte rivers.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
North Fork.	*Feet.*	*Feet.*	*Miles.*	*Ft. per mile.*
Webster†	9,005			
		422	3.11	135.69
Grant†	8,583			
		541	6.14	88.11
Slaght's†	8,042			
		301	5.42	55.54
Bailey's†	7,741			
		166	2.99	55.52
Estabrook Park†	7,575			
		489	3.83	127.68
Grosson†	7,086			
		152	1.82	83.52
Thompson†	6,934			
		168	3.64	46.15
Pine Grove†	6,766			
		119	2.73	43.59
Buffalo†	6,647			
		169	2.58	65.50
Park Siding†	6,478			
		117	3.23	36.22
Vermillion†	6,361			
		248	4.30	57.67
South Platte†	6,113			
		235	2.67	88.01
Deansbury†	5,878			
South Platte river.		358	6.63	54.00
Platte Cañon†	5,520			
		139	9.56	14.54
Littleton†	5,381			
		149	8.14	18.30
Platte bridge†	5,232			
		34	2.46	13.82
Denver (center Seventeenth street)†	5,198			
		231	22.00	10.50
Near Hughes‡	4,967			
		306	32.00	9.57
Evans†	4,661			
		1,917	231.00	8.30
Mouth of river§	2,744			

* Distances above Denver are by railroad; below Denver they are by map measurement.
† Railroad elevations, Denver, South Park, and Pacific railroad.
‡ Water surface at Union Pacific railway crossing.
§ Water surface, estimated.

On leaving the mountains the Platte soon takes on those features which characterize the remainder of its course. Its slope is quite uniform, but gradually decreases toward the mouth; the current is very swift, especially in high water. The bed, which in the mountains contains many large bowlders, is now composed at first of pebbles, gravel, and some bowlders; farther down stream these are succeeded by coarse sand, and not far below Denver is encountered quicksand, which continues thence to the mouth. It is said that the beds of the Platte and its tributaries, in the open country east of the mountains, are composed of sand to a great depth, while beneath the surrounding country rock is encountered at a moderate distance down; if this is true, it indicates that these streams flow along the courses of what were once cañons, but which have become filled up by deposits. The banks are of sandy loam and average from 5 to 6 feet in height in the upper course, but not more than 4 feet toward the mouth.

The river is bordered by bottom-land, which, in the vicinity of Greeley, is in places 3 miles wide, while in others the bluffs close in and form narrows. At Denver the Platte is 150 to 200 feet wide and 4 feet deep in ordinary low water; at mean high water it runs much more rapidly than before, with a width of 500 to 800 feet, and a depth of 7 feet. Below Denver it widens out, its channel becomes very changeable, and sand-bars are frequent. Above the mouth of the Poudre the high-water width is about 700 feet and the depth 6 feet; the river widens greatly to the eastward, and in its lower course averages little less than half a mile across, with a depth, at medium stage, of 12 to 18 inches.

The volume of flow shows large fluctuations if an entire year is considered, but from month to month is comparatively steady; the river rises from May or June to July, and then falls steadily till September, after which

it remains at a low stage till the succeeding spring. To the eastward from Greeley, and thence to the mouth, it rapidly subsides after the June rise, soon disappears in its sandy bed, and apparently dries up; there is, however, a sluggish current of water percolating through the sand. The river continues dry till late in the fall. I was informed at North Platte, near the mouth, that the constantly extending use of the Platte for irrigation in Colorado during the past few years has had a marked effect on the volume in its lower course, causing the river to run dry earlier, and for a longer period, than formerly.

Although the stream runs with full banks during the June rise, it never overflows them. There is no other regularly-recurring freshet, but sudden and brief rises are liable to occur during the period of summer rains. Some years ago there was a "cloud-burst" on the upper river, which caused great damage at Denver; at that time a large volume of water came down the South Platte, and at its mouth presented a front like a wave several feet in height, and gave out a dull roaring sound which could be heard at a considerable distance. The South Platte is free from ice-gorges. No timber is found along its course below the mountains, except occasional slight fringes of cottonwood. The surrounding country is an open rolling prairie.

After issuing from the mountains, near Platte cañon, the river is repeatedly and largely drawn upon for the wants of irrigation. Near the close of 1880 an English company, having its principal office at Denver, was engaged in constructing an irrigating-canal running from the mouth of Platte cañon, 150 miles long, 40 feet wide at the bottom, and 7 feet deep; this canal was designed to irrigate 50,000 acres of land at the start, and when developed to its full capacity, 150,000 acres. (*a*) The dam at the entrance to this canal is 150 feet long, 12 feet high, and cost about $6,000; it is a framed structure, consisting of bents 12 feet high placed at intervals of 8 feet across the stream; these are timbered over and the open spaces filled in with rock.

In the vicinity of Denver no less than eight irrigating-canals run from the Platte. They usually have rude, cheap dams of brush or bowlders at the head, intended merely to divert a sufficient supply of water into the canals. The use of the Platte in this manner continues all the way from Denver to Greeley, and even extends 70 miles east of the latter place to South Platte and Buffalo. From Denver to Greeley the land along the river is, when irrigated, very valuable for small grains, corn, when the season is not too dry, and potatoes. East of Greeley the bottom-land is good when irrigated, but the bluffs are said to become too sandy to be of value.

At Greeley a flouring-mill of four or five runs is operated by water-power from an irrigating-canal, and I think there are a few small powers similarly located on canals in the vicinity of Denver. I was informed, however, that at only one point had a dam been constructed across the Platte for the purpose of obtaining power, and that was a short distance above Denver. This dam rests upon bed rock, and is partly of stone and partly of brush; it was built in 1879, and cost about $3,000. The portion consisting of stone is 150 feet long, 6 feet high, 4 feet wide at the base, and 1½ feet wide at the top; the part built of brush is 250 feet long, with a height diminishing from 6 feet to zero. The canal running from the dam is about 11,600 feet long, 30 feet wide at the bottom, 8 feet deep, and falls 1 foot to the mile. The pond above the dam contains only a few acres, but there is another of 40 or 50 acres on the line of the canal.

The canal empties into a large well, from which the greater part of the water runs onto two 54-inch turbine wheels, the remainder passing through a filtering-crib into the service-pipe, by which it is conveyed for the supply of the city of Denver. The wheels run under a head of 30 feet, and have a capacity for pumping 6,000,000 gallons a day. Their total horse-power is 600, of which about 300 is commonly used by the water-works and 75 is leased to a flouring-mill. There is sufficient water for running these establishments at full capacity nine months in the year, and one-half capacity the remainder of the time.

TRIBUTARIES OF THE SOUTH PLATTE.—Ascending the river from the mouth to Greeley, we meet successively Lodge Pole, Horse Tail, Pawnee, Beaver, Bijou, Kiowa, Box Elder, Crow, and Lone Tree creeks. They are all of the same general character, and are practically valueless for power. They contribute very little water to the Platte; rising in the open country, where the precipitation is slight, they receive but small assistance from melting snow; they run over quicksand beds, into which they sink, going dry most of the year, and it is only after heavy rains that they contain any water worth mentioning.

Above Greeley, some of the streams coming from the west, and having their sources in the mountains, are of importance, and will be described in detail. Of the lesser tributaries, Sand creek is unimportant; Cherry creek is unreliable; it runs dry in summer, but is used for early irrigation. Bear creek is small, but is used for irrigation; Twin creek is small and unimportant; Plum creek runs dry in summer and is of no consequence. Tarryall creek runs parallel to the Middle Fork of the South Platte, and about 15 miles to the northward. It runs through the mountains, is one of the large branches, and, if favorable locations could be found for mills, would carry moderate powers, and, with sufficient head, even tolerably large ones. None of the streams which I have mentioned are employed for power except Twin creek, which has a small saw-mill.

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a To Mr. E. S. Nettleton, chief engineer in this and other enterprises of the Colorado Mortgage and Investment Company, I am indebted for much information regarding the upper Platte river.

The Cache la Poudre river.—This stream rises in Larimer county, Colorado, in the mountains to the east of North Park; it takes a southeasterly course, and empties into the South Platte a few miles east of Greeley. It has a length by general course of 70 to 80 miles, about half of which lies in the mountains, from which it issues some 8 miles to the west of Fort Collins. During its run through the mountains it passes, now through narrow cañons with almost vertical walls, and again through more open valleys half a mile or a mile wide and containing fertile ground. The mountains are thickly covered with white pine timber, and some spruce and quaking ash. The pine trees are not of large diameter, but they are long and straight and afford a fine quality of lumber, not, however, considered equal to that from Michigan. After leaving the mountains the river flows through a rolling country, which, when irrigated, is suited to the raising of wheat, rye, oats, and which in about every alternate year yields a good crop of corn.

The valley of the Cache la Poudre is noted for its fertility and its value for stock-raising. It is crossed, a short distance east of the mountains, and again near the mouth, by north-and-south railroad lines (branches of the Union Pacific), and a survey has been made for a line to follow up the stream through the mountains, passing thence over into North Park. The only towns of importance on the river are Greeley and Fort Collins, each with about 1,300 inhabitants.

Near Fort Collins the river banks are now and then bluffy, but usually have a height of 5 feet, which increases as the mountains are approached. The bed of the stream is composed of bowlders; these are of large size in the mountains, but grow steadily smaller down stream, till, near the mouth, they are reduced to mere pebbles. The current is very swift; for 8 miles above Fort Collins the average fall is said to be 25 feet per mile, and from Fort Collins to Greeley 15 feet per mile. At the former point the stream is 40 to 50 feet wide in an ordinary low stage, and 4 to 6 inches deep; at mean high water it is 100 feet wide and 5 feet deep. Thence to Greeley the average width in mean high water is about 125 feet, and the depth the same as last given.

From the middle of May to the first of July melting snow and rain cause a period of high water, during which the river runs with a swollen, swift, and muddy current, not safely fordable at any point. After that time it rapidly sinks away, its subsidence being hastened by the withdrawal of large amounts of water for irrigation. It reaches its lowest pitch late in the fall, and remains very low all winter. Besides the regular spring-summer high water, there are some sudden rises which cannot be anticipated. During the period of melting snow a heavy rain will cause a rapid rise of a foot or more at Fort Collins, and such a rise may, indeed, result from a rain alone, unassisted by melting snow. Those exceedingly heavy rains termed "cloud-bursts" sometimes occur on the course of the Poudre. In the period of melting snow the sun beats down very hot during the day, while the nights are cold; consequently, the snow wastes away rapidly during the day, while the action is entirely checked at night, and the river shows sensible, daily fluctuations in volume.

Near its headwaters the Poudre drains Chambers lake, containing perhaps 1½ square miles, and also receives the drainage from some other small lakes. The facilities for storage in reservoirs are said to be very good, and the subject of such improvement has been considerably discussed. There are many natural basins in the open country near the foot-hills of the mountains, and it is considered that large amounts of water might be stored in them at reasonable expense. Already some of them have been improved as storage reservoirs to supply irrigating-canals.

Anchor ice is said to form in the mountains, clinging to the bowlders on the bed of the stream and somewhat obstructing its flow, but the mills at Fort Collins experience no difficulty with ice. There are two flouring-mills at that point, each carrying four runs of stone, and supplied with water through canals each more than a mile long; one has 11 feet head, and the other 23 feet. These mills have sufficient water for running at full capacity the year round, though in some seasons there is not much surplus. I was unable to learn of any other use of water-power from this river. At favorable points in the mountains it might doubtless be employed to good advantage, but in the open country there is but little water left after the wants of irrigation have been met. It is also a disadvantage to use for important powers that the volume shows great fluctuations during the year. During the great "Denver flood" of 1864 the Poudre ran 2 miles wide at Fort Collins.

This river is used to such an extent for irrigation that it may be of interest to explain briefly the manner in which it is put to service. The irrigation systems are commonly constructed by joint stock companies, or associations composed of the owners of land benefited. The law is said to give the preference to irrigating-ditches over mill privileges. Large main canals are run off from the stream at a slight grade, the common velocity of the water in them being about 4 feet per second; they ordinarily cost not far from $1,000 per mile, and are sometimes of great length, following the contours of the hills in very sinuous lines. Near their entrances low cheap dams are thrown across the river; these dams are commonly very rudely constructed of brush or bowlders, and are not tight, but are designed simply to divert sufficient water for supplying the main canals. The latter are tapped at frequent intervals, and through wooden sluices water is drawn off into small ditches or feeders, which run off down the hillsides with gradual slope.

A large share of the water is absorbed into the ground, a portion is directly evaporated, and some of that which leaches through the soil ultimately finds its way back into the river again. Irrigation begins in May, and, so far as the crops are concerned, does not need to be continued more than two months; but the water is a convenience

for stock, and it is customary to leave the ditches open, thus withdrawing a large amount of water at a time when the stream most needs it. The supply of water for the year 1880 scarcely sufficed for irrigation, but it is said that with proper management it can, and will, be made to do much greater service.

The highest point at which much water is taken for irrigation from the Poudre, is about 4 miles above Fort Collins, though I understand that it is used to a small extent nearly to the foot-hills of the mountains. No less than ten canals, ranging from 15 to 30 feet in width at the bottom, and numbers of smaller ones, convey water from the river. The most important one was constructed by an English company, and is known as the Larimer and Weld canal. It branches from the Poudre just above Fort Collins, and is carried easterly across Box Elder and Lone Tree creeks nearly to Crow creek. At the close of 1880 it had been completed for a length of 50 miles, and surveyed for 20 miles farther. The width of the canal at the bottom is 30 feet. Along its course are three lakes or storage reservoirs, containing from 80 to 95 acres each.

Another canal at Fort Collins is 15 feet wide and 11 miles long; and one 10 miles below the town is 25 feet wide and 20 miles long. The main irrigating-canals, being carried along the hillsides, must offer many opportunities for the use of water-power. There are a few instances in Colorado where small powers have been thus developed, and are employed by flouring-mills, but the question of putting the canals to use in this manner has not, I believe, arisen in any cases of importance. I was informed by good authority that probably the establishment of mills to a moderate extent would be permitted along the lines of large canals, provided they were so located that after using the water it might be still further employed in irrigation.

Big Thompson creek.—This is the next tributary of the South Platte above the Cache la Poudre. It runs easterly across the southern part of Larimer county, and empties 6 miles southwest of Greeley. It is about 50 miles long by general course, and has a drainage area of 862 square miles. Its principal tributary is the Little Thompson, which joins it a few miles above the mouth. There are no towns of any importance on the stream, and it has no railroad facilities except those afforded by the Colorado Central line, which follows a north-and-south direction, crossing the main stream at Loveland, and the Little Thompson at Berthoud.

The Thompson is said to be of more even flow than the Poudre, although its volume is not so large as that of the latter; it is used for irrigation, and has one flouring-mill of moderate size a mile below Loveland. Eight miles above Loveland it issues from a cañon in the mountains; its actual length from the mouth of the cañon to its source is 55 miles, in which distance there is a fall of 5,000 feet, or an average of 90.9 feet per mile. From the mouth of the cañon to Loveland, 8 miles, the fall is 500 feet, or 62.5 feet per mile; at Loveland the fall is 17 feet per mile. (*a*)

According to the arrangements in force at the beginning of 1881, of the flow of the stream 2,500 cubic feet per minute was appropriated to manufacturing; the amount appropriated to irrigation was 75 per cent. of the full flow at high water. Measurements of the volume made at a point above the mill-race near Loveland have shown a high-water discharge of about 1,200 cubic feet per second, and a discharge in autumn low water of 125 cubic feet per second. The drainage area above this locality being 509 square miles, the high-water discharge is at the rate of 2.36 cubic feet per second per square mile; that at low water is at the rate of 0.25 cubic foot per second per square mile.

Boulder creek.—This stream heads among the mountains in the southwestern part of Boulder county, Colorado; it flows to the northeast, and, about 10 miles above the point where it enters the South Platte, receives from the north Saint Vrain creek, its principal tributary. Boulder creek has a length of nearly 50 miles by general course, and a drainage area of 936 square miles. It is crossed at the town of Boulder, close to the mountains, by the Colorado Central railroad, running from Denver to Cheyenne, and is followed for 10 miles below Boulder by the Boulder Valley railroad. The principal towns are Boulder, on the main stream, population about 3,100, and Longmont, on Saint Vrain creek, population, 800.

The upper course of the stream lies in the mountains, which are thickly timbered with pine and spruce, and contain gold, silver, and other minerals. Its valley consists of a succession of deep and narrow cañons, with occasional intervals in which it widens out somewhat. The bed is of solid rock in the narrow places, but is covered with bowlders where the stream widens. From the mouth of the cañon to the head of the creek, the distance is 21 miles in a straight line, and probably 30 to 35 miles by actual course. The cañon proper is 13 miles long, in which distance there is a fall of 2,600 feet, or an average of 200 feet per mile; the greatest fall in any one mile is 470 feet, and the least is 96 feet.

A short distance above the mouth of the cañon the stream is tapped, and water is conveyed through an iron pipe to a reservoir for the supply of Boulder. Near its exit from the mountains the creek has a mean low-water width of 50 feet, and a depth of about 8 inches; at mean high water it is perhaps 60 feet wide and 2 feet deep. Below the mountains the fall continues rapid for some distance, and the Boulder Valley railroad, which follows its

a I am indebted to Mr. H. P. Handy, civil engineer, of Loveland, for most of my data concerning this stream.

course, has a grade of about 60 feet to the mile. The banks are of loam, and average 5 feet in height. Large drafts are made upon the volume to meet the demands of irrigation; within 2 miles of the mouth of the cañon there runs from the stream one canal 10 miles long, another of 2 miles, and another of 30 miles, all of large cross-section, and there are others farther down stream.

SOUTH BOULDER CAÑON.

Boulder creek has a comparatively steady flow, being well sustained through a considerable part of the year by the snows in the deep mountain valleys, which are gradually melted away by the sun. There is no danger from ice or from freshets, and a severe flood is unknown. It is thought that a considerable storage capacity might be developed at moderate expense. Numerous small lakes are said to be drained in the upper waters, though there are none of important size.

In the mountains the valley widens out at points sufficiently to accommodate mills, and though the low-water volume is not large, the narrow course, rocky bed, and rapid fall are all favorable to the development of power. The principal objection, however, to this section is its difficulty of access. Below the mountains so much of the water is used for irrigation that little is left in a low stage for any other employment. The only power in use on the stream is at Boulder, but a short distance from the cañon; here are met, successively, in descending the creek, a flouring-mill of five runs, with 30 feet head and 75 horse-power; reduction-works, using 18 feet head and 80 horse-power, with sufficient water at all seasons; a small planing-mill; and, lastly, a flouring-mill of five runs, with 23 feet head, supplied with 60 horse-power by water, and carrying an engine of equal capacity.

Clear creek.—Clear creek rises in the mountains 35 to 45 miles west of Denver, whence it flows easterly to the South Platte. It is about 50 miles long, by general course, to the source of the South Fork, and has a drainage area of 623 square miles. Near Golden it emerges from the mountains, and for the short remaining portion of its course runs through an open, rolling district, which it serves to irrigate. The principal towns are Golden, on the main stream; Central City and Black Hawk, on the North Fork; and Georgetown, on the South Fork. A narrow-gauge railroad runs from Denver up the valley of the stream to Central City and Georgetown.

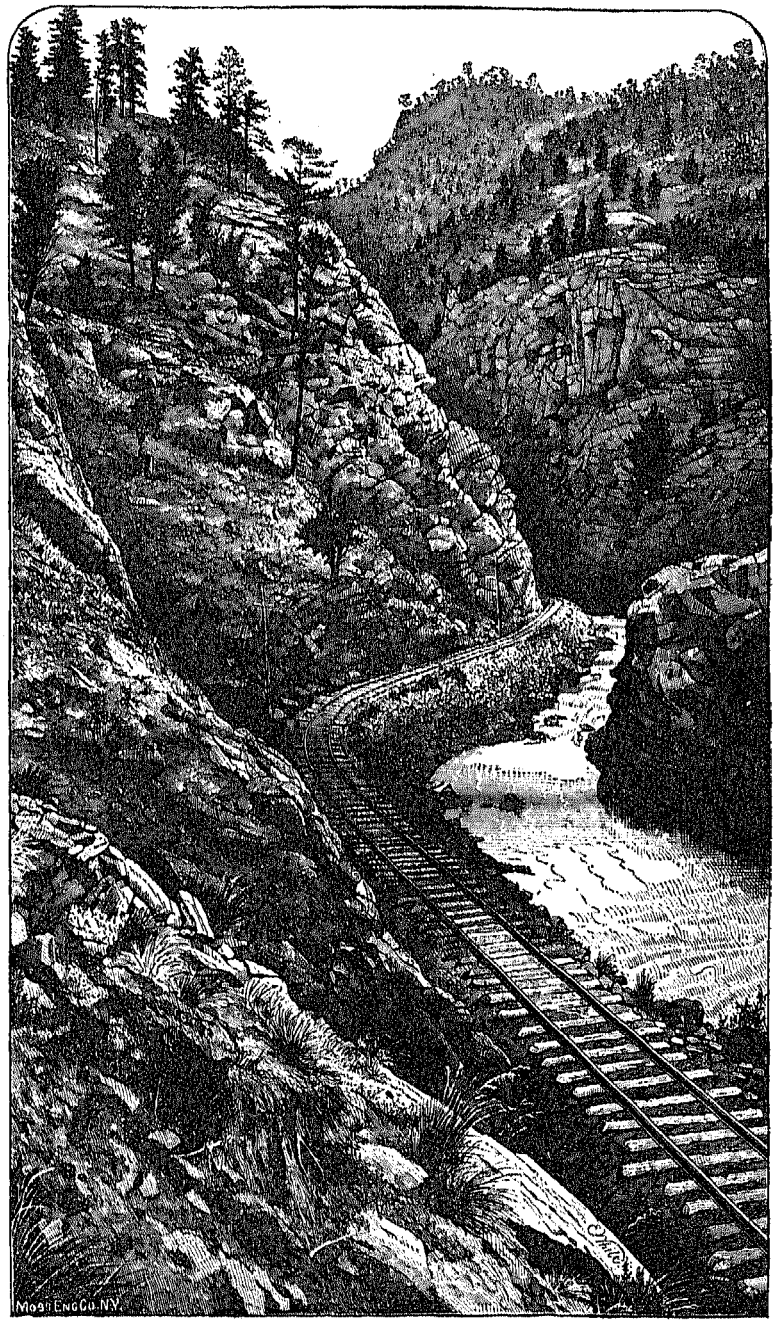
Above the point where it issues from the mountains the course of Clear creek lies through a cañon of remarkable wildness and grandeur. The stream is narrow, commonly ranging from 20 to 50 or 75 feet in width; from either side there rise, with steep and sometimes almost vertical faces, the rocky walls of the narrow valley, hardly leaving room beside the stream for the railroad which runs along its bank. The abrupt slopes rise to heights varying from 1,000 to 2,500 feet; they show but a moderate growth of timber, and their bold outlines and scarred, weather-beaten surfaces render them at once grand and forbidding in appearance. Occasionally the valley widens a little and its sides have an easier slope. On the main stream and on the North Fork the bed consists principally of small bowlders and coarse gravel. The descent is rapid, but there are no abrupt falls of any importance. In times past the bed of North Clear creek has been worked over and over in attempts to find gold, and at frequent intervals there are still to be seen the ruins of old sluices and vertical water-wheels which furnished the miners with small powers.

Ascending South Clear creek from its junction with the North Fork, its course for about 9 miles is in a narrow cañon, shut in by high, vertical walls. The bed is of coarse gravel and bowlders, some of the latter being of great size. At Idaho Springs and above the valley is wider, and now and then there is encountered an open, comparatively level spot, one-half to three-quarters of a mile in width, where the stream has but little fall.

The slope of South Clear creek varies from 40 to 101 feet per mile. On the North Fork and main stream there is a descent of 2,100 feet in the 21 miles from Black Hawk to Golden, or an average of 100 feet per mile, with a range from 49 to 180 feet to the mile. At Golden the fall is 49 to 55 feet per mile. I was informed by Captain E. L. Berthoud, of Golden, who has had an extensive engineering experience in this section, that very accurate levels, run between Golden and Forks Creek (junction North and South Forks), a distance of 13 miles by the stream, showed a rise at the latter point of seven-tenths of a foot between the years 1865 and 1872, thus indicating that the process of elevation was still going on in the mountain mass. A further rise was observed up to Central City, but the levels were not so accurately taken as on the lower section, and the result was not, therefore, so reliable.

At Golden and in the vicinity four irrigating-canals make heavy demands upon the stream, and below that locality it has no value for power. Aside from agriculture, which is confined to the section east of the mountains, the principal industries of Clear Creek valley may be said to be concentrated at Golden, Central City, and Georgetown, and those are the only points where water-power of any consequence is in use.

Golden is an important manufacturing place, and has fine advantages. It lies at the outlet of the mountain valley, through which comes the product of many valuable mines, yielding large amounts of lead and copper, as well as gold and silver. Deposits of iron ore, lignite, coal, and brick clay are found near at hand. Water is taken from the creek in races, or ditches, as they are called, one of which supplies a small paper-mill and a flouring-mill of four runs; the latter mill has 19 feet head and uses 65 horse-power. Another ditch carries water to a three-run flouring-mill, with 14 feet head and 40 horse-power. There is still another flouring-mill, which was not in operation at the time of my visit. Four smelting and reduction works also take water at this point from Clear creek, though they do not employ it for power.



ROCKY POINT, CLEAR CREEK CAÑON.

Central City and Black Hawk, which are continuous and form practically one and the same town, lie in a deep valley high up among the mountains, and nearly or quite 8,000 feet above sea-level; their chief industry is gold mining. Dwelling-houses and other buildings are scattered for some distance up the sides of the valley, while along the bottom courses the little stream called North Clear creek, bordered by the stamp-mills belonging to the different mines. These mills use the stream for power and otherwise in the operations of pounding up the ore and removing the gold. On leaving them, its waters, clear and transparent at the start, have become turned to a milky hue. The dams are rude, short, and insignificant; the water is conveyed through wooden sluices to the wheels, which are overshot or breast, employed in preference to turbines as giving a slower motion and being on other accounts better suited to the style of work. The principal concerns, in order from the upper end of the valley, are as follows:

1. Wheeler and Sullivan mill; wheel 25 feet in diameter; runs 25 stamps in summer.

2. Fullerton's mill; wheel 22 feet in diameter; runs 33 stamps.

3. Arige and White's mill; breast-wheel, 12 feet in diameter; runs 10 stamps.

4. Zinzendorf mill; overshot wheel, 25 feet in diameter; runs 25 stamps.

5. Fullerton's lower mill; breast-wheel, 25 feet in diameter; runs 40 stamps in summer.

6. Kimber mill; breast-wheel, 22 feet in diameter; can run 35 stamps in summer.

7. Bobtail mill; breast-wheel, running under 21 feet head, and estimated at 40 horse-power; has enough water to run at full capacity five months in the year, but steam is used the remainder of the time; 40 stamps, I believe, are run.

8. New York mill; breast-wheel, 33 feet in diameter and 5 feet wide; 25 horse-power obtained eight months in the year, and 50 horse-power four months.

9. French's mill; overshot wheel, 25 feet in diameter and 5 feet wide; in summer can run 35 stamps, each weighing 600 pounds, and making 28 strokes per minute.

Georgetown is a great silver-mining center, and lies in a deep valley, perhaps half a mile to a mile wide, shut in by the almost vertical faces of the mountains, which rise 1,500 to 2,500 feet above the stream. South Clear creek here flows through a flat, sandy piece of ground, which it overflows in high water. It divides into two small branches, on one of which power is used by the Clear Creek Company's reduction works. Power is taken from a "hurdy-gurdy" impact wheel 8½ feet in diameter and 6 inches broad; it runs under a head of 220 feet, water being brought from a point up the valley 1,440 feet in an iron pipe. The supply of water is sufficient for running at full capacity throughout the year. On the other branch G. W. Hall & Co. have a saw-mill and ore-sampling works, and use a 30 horse-power turbine wheel running under 18 feet head. On the same branch are the Farwell reduction works, using an 80 horse-power "hurdy-gurdy" impact wheel with 120 feet head; water is brought to this wheel through 1,300 feet of iron pipe. The wheel makes 1,058 revolutions per minute; it is wasteful of water, and is supplemented by a turbine when the stream is low.

In the open country near the mountains there are numerous depressions, probably dating from glacial times, which can at moderate expense be turned into storage reservoirs, and this improvement has already been effected in some cases for the purposes of irrigation.

The discharge of Clear creek has been repeatedly measured, at intervals over a period of twenty years, by Captain Berthoud, the results of whose observations are given in the table below. The measurements include the whole volume naturally belonging to the stream at Golden, undiminished by withdrawals into races or canals. With reference to rainfall Captain Berthoud divides the water-shed into two zones:

The first zone is that portion that extends along the foot-hills and in the immediate valley of Clear creek and its tributaries to Georgetown, Bakerville, Upper Empire, Black Hawk, Central and Quartz valley. The second zone includes the whole mountain range around Bergen Park, head of Beaver creek, Soda, Chicago, South and West Clear creeks above Georgetown, Bakerville, Upper Empire, Central, Nevada, and Mountain City.

In the first zone the yearly rainfall varies from 13½ to 18¾ inches. In the second zone it varies from 18¾ to 31½ inches, and for the entire area is estimated to average 20.62 inches.

Discharge of Clear creek, as measured by Captain E. L. Berthoud.

[Drainage area above Golden, 436 square miles.]

Stage of water.	Cross-sectional area in square feet.	Average velocity in feet per second for entire cross-section.	Volume in cubic feet per second.	Volume in cubic feet per second per square mile.
High water	280.23	4.27	1,197	2.75
Medium stage	121.07	3.84	465	1.07
Low water, average year	33.07	2.22	75	0.17
Low water, ordinarily dry year (approximate)	25.50	2.10	54	0.12
May 19 to August 27 (100 days), average of years*	104.82	3.24	631	1.45
August 27 to May 19 (265 days), average of years*	57.00	1.84	105	0.24

* Estimated by Captain Berthoud.

From these results it appears that the average annual discharge is about 38 per cent. of the rainfall.

Drainage areas of tributaries of the Platte, North Platte, and South Platte rivers.

Stream.	Tributary to what.	Drainage area.	Stream.	Tributary to what.	Drainage area.
		Sq. miles.			*Sq. miles.*
South Platte, below South Fork	Platte	709	Plum creek	South Platte	826
South Platte, below Tarryall creek	do	1,027	Bear creek	do	279
South Platte, below North Fork	do	2,063	Cherry creek	do	459
South Platte, at Denver	do	3,993	Clear creek	do	623
South Platte, at Greeley (below Poudre)	do	9,807	Boulder creek	do	930
South Platte, at mouth	do	24,408	Thompson creek	do	862
North Platte, at Fort Steele	do	3,050	Cache la Poudre	do	2,614
North Platte, at Fort Fetterman	do	17,150	Crow creek	do	1,546
North Platte, at Fort Laramie, including Laramie river.	do	24,000	Box Elder creek	do	675
North Platte, at mouth	do	35,574	Kiowa creek	do	797
Wood river	do	718	Bijou creek	do	1,458
Prairie creek	do	578	Beaver creek	do	1,300
Loup river	do	15,553	Pawnee creek	do	817
Shell creek	do	533	Horse Tail creek	do	484
Elkhorn river	do	6,732	Lodge Pole creek	do	3,036
Salt creek	do	1,016	Medicine Bow river	North Platte	2,432
Platte, at mouth	Missouri	90,407	Sweetwater river	do	4,037
South Fork	South Platte	430	Poison Spring creek	do	1,429
Tarryall creek	do	484	Laramie river	do	4,500
Trout creek	do	223	Raw Hide creek	do	632
North Fork	do	518	Horse creek	do	1,942

Estimated volume and horse-power of some of the tributaries of the Platte and South Platte rivers.

Stream and locality.	Approximate rainfall on drainage area.					Drainage area.	Low water, ordinarily dry year.		Low water, average year.		Available 10 months in average year.	
	Spr.	Sum.	Aut.	Wr.	Yr.		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches*	*Sq. miles.*						
Salt creek, at Newton	9	13	6	2	30	815	35	40	45	51	70	80
Salt creek, at mouth	9	13	6	2	30	1,616	70	80	85	97	140	159
Elkhorn, at Neligh	6	8	3	2	19	2,057	70	80	115	131	140	160
Elkhorn, below North Fork	6	9	3	2	20	3,378	120	136	200	227	250	284
Elkhorn, at West Point	6	9	3½	2½	21	4,309	160	182	270	307	330	375
Elkhorn, at mouth	7	9	3½	2½	22	6,732	260	295	430	488	540	613
Maple creek	7	10	5½	2½	25	477	20	23	30	34	45	51
Logan creek	7	10	5½	2½	25	1,051	40	45	80	91	100	114
Cache la Poudre at Fort Collins*	5½	6	4½	2½	18½	1,233	150	170	190	216	260	295
Big Thompson, at Loveland*	5½	6	4½	2½	18½	500	60	68	75	85	100	114
Little Thompson, at Berthoud*	5½	6	4½	2½	18½	171	20	23	25	28	35	40
Saint Vrain, at Longmont*	5½	6	4½	2½	18½	324	35	40	45	51	60	68
Boulder, at Boulder*	5½	6	4½	2½	18½	142	15	17	20	23	30	34
Clear, at Golden*	6½	6	4½	3½	20½	436	54	61	75	85	100	114

*Estimates are for natural flow, undiminished by withdrawals for irrigation.

Power utilized on Platte river and tributaries.

[Not including power used in Wyoming or in mining operations in Colorado.]

Stream.	Tributary to what.	State.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Platte	Missouri	Nebraska	Polk	Flour and grist	1	8	36
Do	....do	....do	Merrick	....do	*5	46	217
Do	....do	....do	Hall	....do	1	8½	23
Salt	Platte	....do	Saunders	....do	1	7	40
Do	....do	....do	Lancaster	....do	3	34	94
Small streams	Salt	....do	Saunders	....do	6	78	219
Do	....do	....do	Lancaster	....do	4	48	123
Elkhorn	Platte	....do	Douglas	....do	1	6	62
Do	....do	....do	Washington	....do	1	6	43
Do	....do	....do	Cuming	....do	1	8	95
Do	....do	....do	....do	Paper	1		65
Do	....do	....do	....do	Saw	1		20
Do	....do	....do	Antelope	Flour and grist	1	8	66
Tributaries	Elkhorn	....do	Dodge	....do	4	51	212
Do	....do	....do	Cuming	....do	1	16	24
Do	....do	....do	Burt	....do	2	15	99
Do	....do	....do	Madison	....do	3	36	115
Do	....do	....do	Antelope	....do	1	16	63
Do	....do	....do	Holt	....do	1	14	22
Shell	Platte	....do	Colfax	....do	3	40	221
Do	....do	....do	Platte	....do	1	14	28
Tributaries	Loup	....do	Howard	....do	4	44	92
Do	....do	....do	Greeley	....do	1	9	9
Do	....do	....do	Boone	....do	2	21	95
Do	....do	....do	Buffalo	....do	1	6	14
Wood	Platte	....do	Hall	....do	1	11	30
Do	....do	....do	Buffalo	....do	2	25	102
Small streams	....do	....do	Cass	....do	2	40	32
Do	....do	....do	Butler	....do	1	12	12
South Platte	....do	Colorado	Arapahoe	Water works (Denver)	1	30	600
Tributaries	South Platte	....do	....do	Flour and grist	7	66	505
Cache la Poudre	....do	....do	Larimer	....do	2	34	115
Small stream	Cache la Poudre	....do	....do	Saw	1	20	14
Big Thompson	South Platte	....do	....do	Flour and grist	1	19	40
Boulder	....do	....do	Boulder	....do	2	53	135
Saint Vrain	Boulder	....do	....do	....do	4	101	172
Small stream	....do	....do	....do	Saw	1	18	12
Clear creek	South Platte	....do	Jefferson	....do	1	16	46

Power utilized on Platte river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Clear creek	South Platte	Colorado	Jefferson	Paper	1	18	70
Do	do	do	do	Flour and grist	3	39	130
Do	do	do	Clear Creek	Saw	1	12	30
Small stream	Clear creek	do	do	do	1		25
Twin	South Platte	do	Park	do	1	16	20
SUMMARY.							
Platte	Missouri	Nebraska		Flour and grist	*7	62½	276
Salt	Platte	do		do	4	41	134
Tributaries	Salt	do		do	10	126	342
Elkhorn	Platte	do		Flour and grist (1 paper and 1 saw).	6	28	351
Tributaries	Elkhorn	do		Flour and grist	12	148	535
Shell	Platte	do		do	4	54	240
Tributaries	Loup	do		do	8	80	210
Wood	Platte	do		do	3	36	132
Small streams	do	do		do	3	52	44
South Platte	do	Colorado			1	30	600
Tributaries	South Platte	do			26	412	1,284
Total					84	1,000½	4,157

* Some of these may be on tributaries.

THE LITTLE NEMAHA RIVER.

This is a small stream rising in Otoe county in southeastern Nebraska; it pursues a southeasterly course through Otoe and Nemaha counties, and empties into the Missouri at Nemaha City. It is 60 miles long by general course, and drains an area of 990 square miles. The surrounding country is rolling, and yields well in wheat and corn. Sandstone and limestone suitable for building are found in the counties above mentioned, and a moderate amount of timber occurs along the course of the stream, consisting mainly of walnut, oak, and elm. From the mouth of the stream a branch of the Burlington and Missouri River railroad runs north along the Missouri to Nebraska City; another branch follows the upper river above Syracuse, but the intervening portion is without direct railroad facilities. Syracuse is the largest town on the river, and has about 500 inhabitants.

The river flows in a broad alluvial bottom, bounded by lines of well-rounded bluffs. The bed consists of mud to a depth of 2 or 3 feet, underlaid by clay. The banks are of loam, and 5 to 10 feet high. Toward the mouth the stream is about 150 feet wide. It does not overflow its banks seriously. The freshets to which it is subject are generally caused by the heavy rains of early summer, though they sometimes arise in spring from suddenly melting snow. The flow of the stream is said to be quite steady; toward the mouth the current is sluggish, and during high water the mills are troubled for a month or six weeks by backwater.

I have no exact elevations of the water surface of the Little Nemaha. The mouth is approximately 915 feet above sea-level, and the railroad grade at Syracuse is given as 1,064 feet above the same plane. The distance between these points is 36 miles by general course, for which the fall probably averages from 3 to 4 feet per mile.

Power is used from this river by a number of flouring- and grist-mills, which carry from one to three runs of stone each, and obtain heads of 5 to 16 feet. The dams are said to be mainly brush, and to range in length from 100 to 150 feet, and in height from 7 to 10 feet. The lowest power on the river is at Nemaha City, near the mouth, and is used by a two run flouring-mill. The dam consists of a row of piles, backed with loose stone and rubbish. The piles are 16 feet long, 15 inches in diameter, and in mid-stream are about 4 feet apart. This dam was built in 1880, and seems to answer its purpose well enough thus far, though it is not tight. It is 150 feet long, with an average height of 7 to 8 feet, and cost about $1,500.

The rainfall on the basin of this river may be taken as in spring, 9 inches; summer, 15 inches; autumn, 7 inches; winter, 2 inches; year, 33 inches. I estimate the discharge available during ten months in an ordinary year as below:

Locality.	Drainage area in square miles.	Volume, in cubic feet per second.	Theoretical horse-power, 10 feet head.
At Howard	788	90	102
At mouth	990	110	125

Power used on the Little Nemaha river.

Stream.	Tributary to what.	State.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Little Nemaha	Missouri	Nebraska	Nemaha	Flour and grist	5	47	151
Do	do	do	Otoe	do	4	52	77
Total					9	99	228

THE NEMAHA RIVER.

The main Nemaha is formed by the union of its North and South Forks, in Richardson county, Nebraska, and lies some 20 miles south of the Little Nemaha. From the head of the North Fork to the mouth of the main stream the distance is 88 miles by the general course of the river. The entire drainage area of this river measures 1,924 square miles, of which 600 is in Kansas. The region thus included is a good farming district, contains an abundance of very fine limestone for building, and has some coal. Fringes of timber occur along the river and its tributaries, principally elm, black walnut, cottonwood, and box elder. The surface of the country is mainly undulating prairie, about 3 per cent. being timbered and 10 per cent. bottom-land. (*a*) A division of the Burlington and Missouri River railroad follows the Nemaha and its North Fork, from mouth to source, and then passes on to Lincoln, the capital of Nebraska. The principal towns on the river are Falls City, population 1,600, and Tecumseh, population 1,300.

The rails of the Burlington and Missouri road have an elevation of 865 feet above the sea at the crossing near the mouth, and 1,075 feet at Tecumseh. The intervening distance is by general course 55 miles, for which there is, as above, a fall of approximately 210 feet, or very nearly 4 feet per mile.

The river runs through an alluvial bottom, which ranges from half a mile to a mile and a half in width, and is flanked by gently-rounded bluffs, handsomely terraced in places. The banks of the main stream are clayey, and rise 10 to 25 feet in height above low water. The bed is muddy in that stream, but in the South Fork contains frequent ledges of limestone; in the North Fork the bed is rock, gravel, and clay. These two forks are said to be of about equal size. Near Falls City the main river averages, at low water, 75 feet in width and 2 feet in depth, but at high water it runs with full banks, probably 100 feet wide and 20 feet deep. Occasionally it overflows its banks and spreads out to a width of half a mile or a mile. The fall of snow in this section is not commonly sufficient to cause a heavy freshet, and the extraordinary size noted above results from the heavy rains of early summer. The ordinary rise in the lower river is about 15 feet.

The Nemaha has quite a steady flow from month to month; its current is sluggish in low stages, but in high water it is a rapid stream. The mills experience no trouble with ice. The North and South Forks are each about 40 feet wide. Both upon them and upon the main river water-power is used by numerous flouring-mills. The dams are said to be usually of brush, costing $700 to $800 each. They are, on the average, perhaps 80 feet long and 8 to 15 feet high. The ponds formed are mainly confined within the natural banks of the river. At Falls City, on the main stream, a privilege is occupied by the Falls flouring-mill, carrying three runs of stone. The river had a natural fall at this point of 4 feet over a ledge of blue limestone. The dam is simply a stone wall, 5 feet high, 18 inches thick, and 100 feet long, backed by a mass of brush, loose rock, and earth. It would now require probably $1,000, according to the owner's estimate, to replace it; it was built in 1857, and is reported to have stood well; the annual cost for repairs is about $100. The wheel furnishes 40 horse-power under a head of 10 feet. There is an abundance of water for running day and night at all seasons.

Estimated volume and horse-power of the Nemaha river.

[Available ten months in an average year.]

Locality.	Drainage area in square miles.	Volume, in cubic feet per second.	Theoretical horse-power, 10 feet head.
North Branch, at Tecumseh	306	35	40
North Branch, at mouth	605	70	80
South Branch, at mouth	770	90	102
Main stream, at junction North and South Branches	1,375	150	170
Main stream, at mouth	1,924	210	239

a These are the returns for Nemaha county, Kansas, but probably are not far out of the way for the rest of the basin.

Power used on the Nemaha river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Nemaha	Missouri	Nebraska	Johnson	Flour and grist	3	35	69
Do	do	do	Pawnee	do	2	24	70
Do	do	do	Richardson	do	6	56½	224
					11	115½	363
Muddy creek	Great Nemaha	do	do	do	2	22	51
Walnut creek	do	Kansas	Brown	do	1	13	50
Total					14	150½	464

THE KANSAS RIVER.

The next great river south of the Platte is the Kansas, or, as it was called by the Indians, Kaw; and, like the former stream, it receives the drainage of a large tract of those vast prairies which are spread out to the west of the Missouri. The Kansas river, as such, is comparatively a short stream, being formed at Fort Riley, in Davis county, Kansas, by the union of the Republican and Smoky Hill; but through these rivers and its other tributaries it reaches out over a wide region, and the entire system is very extensive, embracing in its drainage basin 59,750 square miles, of which 8,420 lies in Colorado, 16,430 in Nebraska, and 34,900 in Kansas.

The area thus included has an extreme length from east to west of 485 miles; it is 190 miles wide in the broadest part, and has an average width of not far from 140 miles. The country presents, throughout, essentially the same general appearance, so far as the contour of its surface is concerned; it is a rolling prairie, through which meander the streams in winding courses, running through broad and fertile bottoms flanked on either side by bluffs. In the eastern part of Kansas the rivers are fringed with groves of timber, but as we advance to the westward this becomes more and more scant, and practically disappears at the ninety-ninth meridian. The soil is very fertile, and produces large crops of corn, wheat, and other grains. West of the limit above mentioned, however, the rainfall is unreliable, and failures of crops are common. The soil continues of natural richness over the greater part of the state, but toward the Colorado boundary it grows light and sandy, and is said to have but little value.

To come more directly to the main river, it must be noted that the country bordering its course is a well-settled farming section, and contributes to the growth of numerous thriving towns and cities. Kansas City, which is at the mouth, on the Missouri river, has a population of about 56,000. Following up the stream, the more important places are Lawrence, 8,500 inhabitants; Topeka, 15,500; Saint Mary's, 900; Wamego, 1,800; Manhattan, 2,100; and Junction City, at its head, 2,700. Good building stone is abundant, and there are valuable limestone quarries at Manhattan, Lawrence, and other points. The Junction City limestone, which is largely used for building, is fine-grained, and so soft that it can be sawed and planed with the ordinary tools of a carpenter. It hardens on exposure, is very durable, and has been successfully used for bridge-piers.

The Kansas river flows through a rich alluvial bottom, and has considerable timber bordering its lower course. In the neighborhood of Saint George, some 6 miles below Wamego, and again at Rocky Ford, 18 miles above Topeka, the river bed contains rock and bowlders, but in general it is composed of sand, and frequently of quicksand. Mr. J. B. Whitaker, city engineer of Topeka, states that in that section the quicksand commonly reaches a depth of 6 to 8 feet. At that depth there is encountered a compact layer, 2 to 4 feet thick, of fine sediment. It is very elastic, and when piles are driven upon it they at first rebound, as though from rock, but penetrate with successive blows. Below this layer quicksand is again encountered. The banks are sandy, and easily cave in; one bank is usually higher than the other, rising about 25 feet above low water, while the lower one has a height of only 10 or 12 feet. The channel generally hugs one bank or the other, and is somewhat shifting. Islands are formed here and there by the deposit of sediment during high water. Drift lodges upon them, and there soon springs up a thick growth of brush, mainly cottonwood.

At Topeka the river is 900 feet wide between banks. At ordinary low water the channel occupies 150 to 200 feet of this width, having a depth of 8 to 9 feet; over the remaining width the depth is only 1½ to 2 feet. At mean high water the stream probably averages 10 feet in depth for the entire distance between banks. As with the other streams of this section which have been described, so with the Kansas, highest water usually occurs in June or July, the season of heavy rains. An important rise may occur at other seasons, and sometimes results from melting snow in spring, but in the upper basin the snowfall is light, and since the river does not reach to the mountains it can receive no accessions from that source, as does the Platte. Up to the year 1881 it had only been known to

overflow extensively once in twenty-five years. In 1844 there was a famous freshet, when the river rose 30 feet and flooded the bottoms. Again, in 1858 it rose 24 feet, but in ordinary years the extreme range between high and low water is only 14 to 16 feet. Local storms sometimes occur in the valleys of the tributaries of such violence that those streams pour large volumes of water into the main river and cause, temporarily, an up-stream current in the latter above their mouths. In ordinary years there is not a heavy run of either ice or drift in this river.

The Kansas River valley has good railroad facilities. The Kansas Pacific road, from Kansas City to Denver, runs along its north bank; it is skirted on the south side, from Topeka to the mouth, by the Atchison, Topeka and Santa Fé, and is also crossed by north-and-south lines. The subject of improving the river for navigation has been considered, and, under the direction of Major Suter, an examination was made in 1878, with reference to that object. From the report of that examination it appears that as early as 1855 boats plied between Topeka and the Missouri, and now and then found their way as far west as Fort Riley, 185 miles from the mouth. At present, however, the river is not navigable. From Junction City to Topeka, about 100 miles, the least low-water depth is 12 inches, and thence to the mouth, say 90 miles, it is not less than 2 feet. The chief natural obstructions are shifting sand-bars, snags, and occasionally rocks; navigation is also artificially hindered by a dam at Lawrence, and by ten bridges, located at various points, and all unprovided with draws.

A rough estimate gave $450,000 as the total cost of improving the river so as to insure a channel depth of 4½ feet from the mouth to Topeka, and 3½ feet above that point. The proposed plan of improvement was to clear away snags and rocks, and to contract the water-way by the construction of dikes of brush and stone. The above estimate did not provide for a canal around the Lawrence dam, or for the introduction of draws into the bridges. No work has been undertaken upon the river thus far.

Slope of the Kansas river (water surface).

Locality.	Elevation above sea-level.	Distance between points.	Fall between points.	Fall between points.
	Feet.	*Miles.*	*Feet.*	*Ft. per mile.*
Mouth of Republican river	1,070.60			
Manhattan	1,024.10	24.00	46.5	1.92
Saint George	1,004.85	13.50	19.31	1.43
Wamego	987.95	10.25	17.5	1.71
Saint Mary's	953.35	14.00	34.0	2.43
Topeka	893.15	32.50	61.2	1.88
Lawrence, above dam	824.35	37.25	67.8	1.82
Lawrence, below dam	815.25	.....	9.1	.....
Tiblow	778.75	30.50	41.5	1.36
Union Pacific railway bridge, 1½ miles from mouth of river.	740.00	22.00	33.75	1.65

NOTE.—The items of fall between points are as contained in the government engineer's report, already referred to. The elevations above sea-level are obtained by adding these figures to the level of water surface (740 feet) near the mouth of the river, as given by Union Pacific railway profiles. The resulting elevation at the head of the river is 2.66 feet greater than as given independently by Union Pacific railway profiles.

Above Manhattan the width of the river ranges from 200 to 600 feet; between Wamego and Saint Mary's it reaches 900 feet in places. The flow of this stream is said to be quite uniform from month to month, but scarcely any measurements have been made of its actual volume. In 1878, during the examination of the stream by government engineers, a measurement was made between Wamego and Saint Mary's, at a stage about four-tenths of a foot above low water. The volume was found to be 2,500 cubic feet per second, which, for the 55,500 square miles of drainage area above Saint Mary's, corresponds to about 0.045 cubic foot per second per square mile. During the winter of 1874–'75, in an unprecedented drought, the discharge is stated to have been 2,000 cubic feet per second at Topeka. The drainage area above that city being 56,354 square miles, the above figures indicate a flow at the rate of 0.035 cubic foot per second to the square mile.

POWER AT LAWRENCE.—The only point at which water-power is used on the Kansas river is at Lawrence, in Douglas county. At an early day it was considered an available site, and various surveys were made with a view to developing it. The river is there about 600 feet wide, with banks of only moderate height on the north side, while on the south side, on which the city is located, they rise quite abruptly 50 feet or more from the water. A road bridge spans the river immediately above the dam. The Atchison, Topeka and Santa Fé railroad runs along the south bank, and on the north side of the river is the Kansas Pacific line.

The original dam was built in 1872, of logs and brush, after the usual style of brush dams. It rested directly upon sand, however, and in 1874, during a heavy flood, water worked under it, washed away the sand, and carried off 300 feet of the dam. In 1877 the remaining 300 feet was carried away in the same manner. The damage in each case was perhaps $5,000. The scour at the times of these accidents swept away the sandy bed upon which the

old structure had rested, and left a firm foundation for the present one. This new dam was built as the old one gave way; consequently 300 feet of it was constructed in 1874, and 300 feet in 1877. It has a total length of 600 feet, with an average height of 8 feet. The cost of the entire work, including dam and race-way, is roughly estimated at $100,000.

One-half the length of the dam rests upon a rock ledge and one-half upon hard-pan. That portion upon rock is built of large stones laid in cement, is 20 feet wide at the base and 6 feet at the top, sloping both ways. The remainder of the dam is a framed superstructure, resting on cribs filled with stone. These cribs are 50 feet long, and are laid with the stream; they project below the dam, and are planked over so as to form an apron. The crib-work foundation extends from the river bed up to about the level of low water. Above the dam the bed is covered to a distance of 40 feet with loose rock; below the dam the river banks are protected by rip-rap. On the south side of the stream the dam abuts upon the heavy masonry wall of the race-way, and upon the opposite side upon a timber crib filled with stone. The bulkhead at the entrance to the race is protected from ice and drift by a short wing-dam of crib-work. In February, 1881, the river was visited, for forty-eight hours, by a heavy run of ice 15 inches thick, which carried away from the south end of the dam two courses in depth of stone for a length of 200 feet from the shore.

The dam causes slack water for some 6 miles up stream, thus furnishing storage over a surface of 300 to 400 acres, with an average depth estimated at 6 to 8 feet. The race-way is 60 feet wide, and inclosed by heavy masonry walls 18 feet high. It is estimated to carry sufficient water for 500 horse-power. Eight Leffel wheels, ranging from 40 to 74 inches in diameter, are run, under a head of 8 to 9 feet. The only concern taking power directly from the wheels is the Douglas County flouring-mill, power being transferred to the other establishments by the use of wire cables. The loss of power is not considered to be serious, and the system works well. The mills operated by this means are located upon both sides of the river, and at considerable distances from its banks; the longest distance to which power is conveyed is half a mile. Power is supplied to four flouring-mills and two elevators, a foundry and machine-shop, a woolen-mill, a shirt-factory, a hay-press, and a concern for the manufacture of wire fencing, the last five being small establishments. Altogether 250 to 300 horse-power is used. The mills are troubled by backwater about one week in the year.

The Lawrence water-power is now owned by Mr. J. D. Bowersock, of that city. The rate charged for water is $20 a year per horse-power, the latter not measured, but estimated approximately. There is opportunity for the use of a large additional power on each side of the river, and I was informed by Mr. Bowersock that land for mill-sites would probably be given outright to induce the establishment of new concerns. The location is claimed to be valuable for factories to engage in the manufacture of cotton and woolen goods, furniture, paper, boots and shoes, agricultural implements, and oil. Wool is raised in every direction, the adjoining counties produce large crops of castor-oil beans and flax, and it is even stated that cotton may be successfully grown in Kansas.

The Lawrence privilege is claimed to have a capacity, at minimum stage of water, of 1,500 effective horse-power, which appears to be a reasonable estimate, although, in the manner in which the power is improved, and with the use of long cables, it could not all be realized in practice. I estimate the theoretical power as follows:

Estimate of power at Lawrence, Kansas.

[Drainage area, 58,235 square miles.]

	Low water of ordinarily dry year.	Low water of average year.	Available 10 months in average year.
Volume in cubic feet per second	2,200	2,550	3,100
Theoretical horse-power, 1 foot head	240.02	280.68	352.16
Theoretical horse-power, 9 feet head	2,250	2,610	3,170

This estimate assumes the power to be in use day and night; if it be employed but twelve hours daily it may be substantially increased by the large storage above the dam.

UNDEVELOPED POWER NEAR TOPEKA.—From what has been said concerning this river, it may be seen that the chief natural hinderances to its development for power are its width, slight fall, and the sandy nature of its bed and banks, bringing expense and danger in the construction and maintenance of dams. It carries a good deal of sediment, and is visited by occasional heavy runs of ice. There is also a lack of sufficient capital in this section for such enterprises as the development of extensive water-powers. Though the only dam on the river is at Lawrence, the construction of one in the vicinity of Topeka has been considerably discussed. Eighteen miles above the city rapids extend for 200 feet, with a fall of 1.25 foot in that distance; for the 2,700 feet below there is a total fall of 1 foot, or, in all, 2.25 feet in 2,900 feet. The bed of the river is rocky at these shoals, though the engineer's report, previously referred to, speaks of the rocks as appearing to be loose and capable of removal.

Three miles above Topeka there is another location, which is considered suitable for a dam. An article concerning this site says:

The width of the river at that point is 700 feet, the height of the banks such as to allow of the erection of a dam 12 feet in height. The rock bottom which extends across the river is of varying depth, being 2 feet below low water at the south side of the river, and 23 feet at the north side. The rock, with the exception of 50 feet in width on the south side of the river, is covered with sand. The race-way will be built on the south side of the river, and will run along the foot of the bluff, on the chord of which the river is the arc. The length of the race-way will be about 2½ miles, of which distance nine-tenths of a mile will be in the bed of an old wet-weather creek; which, in places, is 30 feet in width, and of a depth far below the bottom of the race-way. The ground between the site of the proposed race-way and the river has, for the most part, an elevation of several feet above high water in the river. The rock on the south side of the river will afford excellent foundations for the south abutment and the head-gates of the race-way.

I should estimate the volume and gross power at this privilege as follows, reckoning upon the constant flow of the stream:

Estimate of power at proposed site near Topeka.

[Drainage area, 56,354 square miles.]

	Low water, ordinarily dry year.	Low water, average year.	Available ten months in average year.
Volume, cubic feet per second	2,100	2,450	3,000
Theoretical horse-power, per foot fall	238.56	278.32	340.80

TRIBUTARIES OF THE KANSAS RIVER.

In describing the tributary streams I shall consider them in order above the mouth of the main river.

The first stream to be noticed is Big Stranger creek, which flows from the north, draining portions of Leavenworth, Jefferson, and Atchison counties. It is small, having a length by general course of about 50 miles, and a drainage area of 545 square miles. I was informed by Mr. D. N. Barnes, surveyor of Leavenworth county, that power is used from the stream by two small mills in that county, one of two runs in Easton township, and one of three runs near the south line of Stranger township. The dams are said to be of stone, laid in cement and backed by gravel. The mills have water enough to run them for about ten months in the year. The stream is sluggish and crooked, has high alluvial banks, a bed mostly composed of thick mud, and shows very few rock ledges. At an ordinary stage it is about 20 feet wide and 1 foot deep, but in high water it runs 200 feet wide and 25 feet deep. It is subject to sudden and heavy rise and fall. Mr. Barnes said there were three fair locations along the stream not improved.

Wakarusa creek flows into the Kansas from the south, a short distance above the Big Stranger, and lies in Douglas and Shawnee counties. It is a small stream, with a drainage basin of 520 square miles. No mills are returned as using power, but I have no further information about it.

The next tributary of consequence is the Delaware river, formerly called the Grasshopper. Its source is in Nemaha county, whence it runs to the south, emptying into the Kansas river 10 miles northwest of Lawrence. It is 70 miles long by general course, and drains 1,200 square miles. At Valley Falls, where crossed by the Atchison, Topeka and Santa Fé railroad, the water surface has an elevation of 901 feet above tide. At the Kansas Pacific crossing, near the mouth, the elevation of the water surface is 850 feet. By map measurement the intervening distance is 26 miles, for which the average fall is thus about 2 feet per mile. Almost every foot of the fall noted above is said to be utilized.

At Valley Falls the river has an ordinary width of about 100 feet. The valley is there a quarter of a mile wide, and well wooded. The river bed in this section is rocky, composed largely of limestone and soapstone, but is also gravelly in places. The banks are alluvial, and about 20 feet in height. Once in a few years the stream overflows its banks and spreads out over the valley. The highest rise was 26 feet in 1858. There has been a marked improvement in the stream in the past twenty years. That length of time ago it had little value; one small mill used it for power, but was obliged to shut down for eight months in the year. The stream was then very flashy, but is now comparatively steady, being much better supplied by springs than formerly.

Beginning at the headwaters, the mills on this stream are said to be located as follows: Muscotah, one mill; Arrington, one mill of three runs; Half Mound, one mill of three runs; Valley Falls, one mill of two runs, and one of four runs; Osawkie, one mill of three runs; and there are possibly one or two others farther down. They are said generally to have framed dams, founded upon rock beds, and to use heads of 7 to 9 feet. I was told that there was one unimproved privilege some 4 miles below Valley Falls, where the bed is soapstone. At the upper mill at Valley Falls 50 horse-power is used, with a head of 8 feet. The dam was built in 1855, at an estimated cost of perhaps $900. It is 115 feet long, 8 feet high, and is a framed structure filled and faced with stone. It rests upon a limestone bed, and abuts at one end upon a masonry wall and at the other upon a crib filled with stone. The pond sets back 5 or 6 miles up the river. At one end of the dam the power is used to run the flouring-mill and a pump

for the railroad water-tank. Power is also carried by cable 250 feet to a one-set woolen-mill, and 800 feet to a grain elevator of 15,000 bushels capacity. There is usually sufficient water to run all these throughout the year, but there is sometimes a scarcity in August and September. The proprietor of the woolen-mill informed me that he found woolen manufacturing unsatisfactory here, chiefly from the difficulty in finding good hands. He manufactures jeans, cassimeres, yarns, and flannels, the two latter articles meeting with ready sale.

The rainfall on the Delaware basin may be taken as in spring, 8 inches; summer, 13 inches; autumn, 8 inches; winter, 4 inches; and for the year, 33 inches. I assume the discharge, available ten months in an average year, and the corresponding horse-power, as below:

Estimated power of the Delaware river.

Locality.	Drainage area, in square miles.	Volume, in cubic feet per second.	Theoretical horse-power, 10 feet head.
Arrington, above Elk creek	612	75	85
Valley Falls	951	110	125
Mouth of river	1,200	140	159

THE BIG BLUE RIVER.

One of the most favorable streams for water-power that I visited in the Missouri basin is the Big Blue river. It is formed in southeastern Nebraska by a number of small forks which rise but a few miles south of the Platte river. The North and West Forks, which are the most important of these, receive several minor streams, and themselves unite a few miles above Crete, in Saline county, Nebraska. The Big Blue then continues southward into Kansas, receiving no important accessions till, just above Blue Rapids, it is joined by the Little Blue. It empties into the Kansas river at Manhattan, 160 miles from the Missouri. From the junction of the North and West Forks the distance to its mouth is, by general course, 100 miles. Its drainage basin has an extreme width of about 120 miles, at the headwaters, but narrows rapidly toward the south, and comprises an area of 9,574 square miles.

The surface of the country drained is a rolling prairie, with but little timber. It is a fine agricultural section, wheat and corn being the chief productions. There is an abundance of good building stone. The river has a railroad skirting the greater part of its course, and is crossed at several points by important east-and-west lines. Beginning at the mouth, the more prominent towns on the river are Manhattan, population 2,100; Blue Rapids, 800; Marysville, 1,200; Blue Springs, 500; Beatrice, 2,400; Wilber, 700; and Crete, 1,900.

The Big Blue has a good fall, numerous exposures of limestone in its bed, a well-sustained and steady flow, and never overflows its banks to an important extent.

Slope of the Big Blue river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Seward†	1,408			
		88	22	4.00
Crete†	1,320			
		107	28	3.82
Beatrice†	1,213			
		81	34	2.38
Marysville‡	1,132			
		108	69	1.56
Manhattan§	1,024			

* Map measurement.
† Elevation of rails, Burlington and Missouri River railroad.
‡ Elevation of rails, Union Pacific railway.
§ Water surface in Kansas river.

Below the junction of the North and West Forks there are said to be flouring-mills at Crete, Wilber, and Caldwell, and there are probably available sites not yet improved. In this section the river ranges from 50 to 100 feet in width, and varies in depth from perhaps 8 inches in low water to 6 or 8 feet at a high stage. From the vicinity of Milford to Beatrice the bed is sandy and unfavorable to dams. It was stated to me that a brush dam at Crete had sunk 8 feet in the sand; and that another, at Wilber, built in horseshoe shape, had caused a very deep hole to be scoured at the center of the river below the dam, and the structure had then fallen in.

At Beatrice there is a frame dam 150 feet long and 7 feet high, resting upon a limestone bed. It was built in 1879 at a cost of $2,000. The pond sets back 2 miles up the river. The privilege furnishes a head of 7 feet, which may be increased to 9 feet. About 75 horse-power is used by a flouring-mill, with four runs of stone and a set of steel

rollers, and an elevator. Only one-half the privilege is thus employed, the remainder being unused. The mill has an abundance of water throughout the year. The river is here 100 feet wide, with banks 10 to 15 feet high. The bottom is 1 mile to 3 miles in width, and is free from swamp-land.

From Beatrice to Marysville the river bed is largely composed of magnesian limestone, with some sand-bars. Deposits of stones, such as jasper, flint, and petrified wood, are found in the bed, apparently transported from a great distance. There are large limestone quarries in the vicinity of the river, which are extensively worked. The stone is soft when quarried, but hardens on exposure. The total fall between Beatrice and Marysville is about 81 feet. I could learn of but two mills in this distance—one of two runs at Blue Springs, having a fine timber dam, and one at Oketo, with a log dam. There are said to be numerous unimproved sites, with rock bottom and available heads of 7 to 10 feet. There were mentioned in particular one 1½ miles below Beatrice; one 5 miles below Beatrice; and one 3 miles below Blue Springs.

The next power visited was that at Marysville, where there is a dam 175 feet long and 9 feet high. It was built in 1862, and consists of brush at the bottom, but above that is mostly loose rock which has been piled on. The pond sets back 3 miles in the river. A head of 9 feet is gained, and power is furnished to a fine stone flouring-mill carrying five runs, and is also transferred by cable to a grain-elevator. The race is a tunnel 250 feet long, quarried through solid rock. There is an abundance of water throughout the year, and even with the present loose dam a large amount of water runs to waste over it at all seasons.

I was informed by Mr. Milliken, county surveyor at Marysville, that from that point to the mouth of the Little Blue, the bed of the main stream consists principally of magnesian limestone. The banks are, for one-third of the way, rocky, and for two-thirds soil and clay, and average about 20 feet in height. All along this stretch there are riffles, and four or five unimproved sites can be found where there is a rock bed and an available head of 7 to 10 feet. One of these sites is about 1 mile below Marysville, and another is in section 19, township 3, range 7. It is thought that the stream might be reservoired if it were desirable. There are numerous side brooks and creeks flowing down through rocky ravines which might easily be dammed. This whole section is underlaid at slight depth by limestone of the best character for building, and the railroad from Beatrice to Marysville passes through quarries of it. Brick clay is also found in abundance. It occurs somewhat in the banks of the Blue, changing in places to a slaty rock.

Power at Blue Rapids.—The most extensively-developed power on the river is at Blue Rapids, in the southwestern part of Marshall county, Kansas. This is a beautiful town of 800 inhabitants, lying on the Central Branch of the Missouri Pacific railway, 95 miles from Atchison. It was colonized in 1869 by a society formed in Genesee county, New York. This association, known as "The Blue Rapids Town Company", purchased a large tract of land here, and set to work to develop a manufacturing town. Thirty or forty thousand dollars was at once expended in constructing a fine dam and improving the river banks. In the course of three or four years, four mills were erected and put in operation, comprising establishments for the manufacture of woolen goods, paper, flour, and plaster. During the financial depression which followed the year 1873 the woolen-mill and paper-mill were compelled to stop, and the Town Company becoming involved, its property passed into other hands. The mills were subsequently started again, and are now actively employed. The present owner of the privilege is represented in Blue Rapids by his attorney, Mr. John V. Coon.

The town takes its name from the natural rapids in the river, in which there is a fall of about 2½ feet in 150. At the head of these rapids, and some 2 miles below the mouth of the Little Blue, is the site of the dam. Directly over it is an iron road-bridge, with two spans of 118 feet each. The dam is crescent-shaped, and consists of two sections, abutting in common upon the pier at the center of the bridge. The west bank is here alluvial, while the east bank and river bed are magnesian limestone. The bed was properly leveled, and upon it was built the dam, of cut stone masonry, 8 feet wide at the base, 4 feet at the top, and 9 feet high. It is backed for 25 feet by loose stone and gravel, and at each extremity abuts upon the heavy race-way walls. In order to prevent water from working around the west end, where the bank is alluvial, a wing-wall has been carried for 50 feet beyond the abutment into the bank. This bank is also heavily rip-rapped both above and below the dam. Running from the dam down the river on each side, the whole length of the mills, there is a very solid masonry wall. The bulkhead on the east side of the river is 40 feet wide; the race has the same width, and is entered through four 8-foot arched openings in the bulkhead. The race on the west side of the river has a width of 25 feet. The present head on the wheels is 11 feet, which can be increased 2 feet by raising the dam.

The mills now in operation own rights to about 400 horse-power. It is estimated that 170 horse-power is actually used by them, (*a*) distributed as follows:

Flouring-mill, 60 horse power (entitled to power for six runs of stone).
Woolen-mill, 40 horse-power (entitled to power for six runs of stone).
Paper-mill, 40 horse-power (entitled to 75 horse-power).
Plaster-mill, 20 horse-power.
Foundery, 10 horse-power.

a Total rated horse-power of wheels about 317.

A wheel in the flouring-mill pumps water for the supply of the town. Besides the above mills, foundations have been laid for another, originally designed as an oil-mill.

The privilege which I have described is about a mile from the railroad, and it is probable that in time a line to follow down the course of the river will run close by it. All the work in connection with the development of the power has been done in the most substantial manner; the mills are built of stone, and it is estimated that an investment of $350,000 to $400,000 is represented at this site. No particular rates are observed in renting power; it is very much desired to attract new enterprises, and any important concern could probably obtain power free. The banks and foundations are very favorable for the location of mills, and power could be transferred to them by cables, or the races might be extended down stream. The woolen-mill is owned by the Buell Manufacturing Company, of Saint Joseph, Missouri, and is said to have met with good success. It manufactures yarns, woolen cloths, flannels, and blankets.

The river in this vicinity runs, at an ordinary low stage, 250 feet wide and 2 feet deep, with a fair current. It has risen once or twice to a height of 18 feet, but does not overflow its banks. Its low-water volume is thought to increase somewhat from year to year, by reason of the breaking up of the soil by cultivation and its consequently greater receptiveness of water. The flow from month to month is very steady. It was stated that, during the year 1880, the depth of water flowing over the Blue Rapids dam varied but three-quarters of an inch in eight months. No trouble is experienced at that point from ice. Backwater causes some hinderance during freshets, but never for a longer time than three weeks in all during the year.

I could find no record of any gauging of the river, but should estimate the power at Blue Rapids, taking the constant flow of the stream, as follows:

Estimated power at Blue Rapids.

[Drainage area 8,310 square miles.]

	Low water, ordinarily dry year.	Low water, average year.	Available 10 months in average year.
Volume, cubic feet per second	590	730	820
Theoretical horse-power:			
1 foot head	67.02	82.93	93.15
11 feet head	740.	910.	1,020.
13 feet head	870.	1,080.	1,210.

There was said to be a good unimproved site for power on the Big Blue, some 6 miles above Blue Rapids, where there is a rock bottom, and a head of 10 feet available. Another good site was mentioned as being undeveloped at Randolph, about midway between Blue Rapids and the mouth of the river, where there is also a rock bottom. There are, doubtless, numerous other available points of which I did not learn.

In its lower course the river is about 250 feet wide, and in medium low water has a depth of perhaps 4 feet, and a moderate current. It runs through bottom-land 1½ miles wide, beyond which rise bluffs 300 feet high. The banks are of loam, ranging from 10 to 30 feet in height. The bed is sandy and gravelly, with frequent limestone ledges. The last dam on the river is at Rocky Ford, 4 miles above Manhattan. It rests upon a rock foundation, and has stone abutments. It is a framed structure, 357 feet long and 10 feet high, and is reported to have cost at least $20,000. The pond sets back for 7 miles. The wheels run under a head of 10 feet, power being used by a flouring-mill with four runs of stone, and a small saw-mill. There is a large surplus of water, estimated at 10 inches in depth, running to waste over the dam at the lowest stage of the river.

The only points in the immediate vicinity of the Big Blue basin at which rainfall observations have been made for a series of years are Omaha and Fort Kearney, in Nebraska, and Manhattan, at the mouth of the river. From the records at these stations the rainfall appears to be about as follows: For the upper basin, spring, 8.5 inches; summer, 13.2; autumn, 5.8; winter, 1.6; year, 29.1; and for the basin as a whole, spring, 8.1 inches; summer, 13; autumn, 6.1; winter, 2.3; year, 29.5. In estimating the volume of this stream, in the absence of any gaugings whatever, I have divided the volume previously assumed for the Kansas river mainly among its three largest tributaries, the Republican, Smoky Hill, and Blue. I have given to the latter stream a considerably higher and less variable rate than to either of the former, in accordance with its character as having a steady and well-sustained flow. This character is probably due to its being well supplied by springs, to the greater cultivation of the soil in the Big Blue basin than in western Kansas and Nebraska, and to the fact that, to a large extent, it flows directly upon the rocky strata, which shed water into it, while the Republican and Smoky Hill are underlaid to a greater or less depth by sand and other surface deposits, which must permit a great deal of water to percolate through them and be lost to the streams.

Estimated volume and horse-power, Big Blue river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Crete	2,711	150	170	220	250	250	280
Beatrice	3,841	240	270	330	370	370	420
Above Little Blue	4,858	320	360	420	480	470	530
Below Little Blue	8,319	590	670	730	830	820	930
Randolph	9,372	660	750	800	910	910	1,030
Mouth of river	9,574	670	760	820	930	930	1,060

TRIBUTARIES OF THE BIG BLUE.—Ascending from the mouth, Fancy creek is the first side stream of any consequence. It enters the main river from the west at Randolph, and is used for power by one small flouring-mill.

The next tributary is the Black Vermilion, which joins the Big Blue from the east about 10 miles southeast of Blue Rapids. It drains an area of 533 square miles, lying mainly in Marshall county. At Frankfort it has a mill of two or three runs. The bed is to a considerable extent rocky, but the stream gets very low in a dry season, and is not of importance for power.

The Little Blue river.—This is the next and most important tributary of the Big Blue. It heads in Kearney and Adams counties, in southern Nebraska, pursues a southeasterly course into Kansas, and joins the Big Blue 2 miles above Blue Rapids. It is 158 miles long by general course, with a drainage area of somewhat uniform width, comprising 3,461 square miles. The headwaters of this stream are within a few miles of the Platte river, and the underground drainage which both it and the Big Blue receive from the Platte has already been discussed in connection with the latter river. For a distance of 40 or 50 miles its course is closely followed by the Saint Joseph and Western division of the Union Pacific railway.

The country drained by the Little Blue is open and rolling. Corn, wheat, and other grains are the chief productions, but toward the headwaters the rainfall is rather scant and unreliable, and failures of crops are not uncommon. The main stream is fringed with cottonwood and box-elder, but there is more timber on the little side streams, consisting of oak, walnut, and ash. There was formerly much more timber in this section than now, but it has largely been cut away, both upon this river and the Big Blue. Building-stone is found at Hanover, Hollenberg, and in Thayer county, but not above. The river bed is sand and gravel, underlaid by a very hard clay which is almost stone. I was informed by Mr. W. W. Watson, (*a*) civil engineer, of Fairbury, that in excavating in the river bed for pier foundations he had found a thin shale, and under this 3 feet of quicksand, underlaid in turn by the hard clay above mentioned. The banks are usually of loam, and 6 to 8 feet high; sometimes, where the stream cuts into the bluff, red sandstone crops out.

The river is bordered by bottom-land averaging a mile or more in width. Beyond this rise, on either side, low bluffs, 50 or 60 feet high. The stream has a swift current and a quite steady flow from month to month. It rises and falls rapidly, however, after heavy rains, and occasionally overflows its banks; it did so in the fall of 1869, and again in 1874. Summer high water commonly sets in about June 1, and a high stage lasts for a week. For that length of time the mills are troubled by backwater. Ice causes no difficulty. Mr. Watson does not consider storage reservoirs very practicable along this stream, even if they were needed. He says there are neither favorable ravines on the small streams nor natural ponds.

Slope of the Little Blue river (approximate).

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Hastings (4 miles from river) †	1,880	502	81	6.9
Fairbury ‡	1,324			
Mouth of river §	1,107	217	47	4.6

* Map measurement.
† Elevation of rails, Burlington and Missouri River railroad.
‡ Elevation as given by Professor Aughey.
§ Elevation estimated.

a I am indebted to Mr. Watson for most of my information concerning this river.

Only a small proportion of the fall of this river is in use, and it was stated that a good available power could be found once in 3 miles, on the average, where 10 feet head might be secured. As nearly as I could ascertain, the locations of the mills on the river were as follows, beginning at the head: Adams county, one mill; Clay county, one mill of two or three runs; Nuckolls county, two mills of two or three runs each; Hebron, one mill of four runs; 5 miles above Meridian, one mill of two or three runs; Meridian, one mill of three runs; Fairbury, one mill of four runs; Steele City, one mill of three runs; Hanover, one mill of four runs; 3 miles above Waterville, one mill of four runs; and at Waterville, one mill of four runs. These are all flouring-mills. The dams are said to range in length from 100 to 200 feet, in height from 7 to 10 feet, and in cost from $1,000 to $3,000. I was told that they were originally of brush in most cases, but are being gradually replaced by crib-work structures, the latter being more permanent and requiring fewer repairs. Brush dams sink in the sandy bed, and settle even on a hard foundation; they also decay quite rapidly, and need repairing every year.

At Fairbury the Little Blue is, at mean low water, about 80 to 100 feet wide, and 2 feet deep; at mean high water it has nearly the same width, but is probably 10 feet deep. The dam at this point was in the first place brush, but a new dam, of crib-work filled with stone, was built in 1877 below the old one, and the intervening space filled with stone. It cost about $3,500, is 150 feet long, 7 feet high, and has stone abutments. The pond extends 1½ miles up the river. The wheels run under a head of 7 feet, and are located in a wheel-pit at one end of the dam. The power is taken from a 61-inch Leffel wheel, and transferred by a §-inch wire cable 730 feet to the mill. The plan is very satisfactory in its working. The wheels are rated at 55 horse-power, and there is a large surplus of water at the lowest stage.

Toward the mouth of the river the bed is generally gravel. As a rule the banks are bluffy on one side, and low upon the other; the low bank is about 8 feet high and is sandy. The stream overflows its banks every few years in this section, and then runs 300 feet or more in width. The extreme freshet rise is 14 feet. The last power on the river is at Waterville, a few miles above the mouth, and is occupied by a four-run flouring-mill, with wheels of 90 horse-power. The dam was built in 1873, and cost $11,000. It is 170 feet long, 15½ feet high above foundation, is of stone laid in cement, and measures 9 feet in width at the base and 6 feet at the top. It rests upon a rock bed, has masonry abutments, and is without any apron. The pond sets back 3 miles. The fall is 6½ feet. There is, of course, an abundance of water at all stages.

Of the tributaries of the Little Blue, the Big Sandy and Rosewater are small and unimportant, but are used by one or two little flouring-mills. Since 1871 the Big Sandy has increased 1½ to 2 miles in the length of running water at a low stage.

The mean rainfall on the drainage basin of the Little Blue is, approximately, in spring, 8 inches; summer, 11; autumn, 5; winter, 1½ to 2; year, 25½ to 26. Further on will be found an estimate of volume and horse-power at different points.

OTHER TRIBUTARIES OF THE BIG BLUE.—Between Beatrice and Crete the Big Blue receives Turkey creek on the west side. It has a drainage area of 686 square miles, lying in Saline and Fillmore counties, and is used for power by several small flouring- and grist-mills.

The West Fork of the Big Blue is formed in turn by Beaver creek and the South Branch, which have their sources respectively in Hamilton and Adams counties, Nebraska, whence they run easterly. The West Fork unites with the North Fork a few miles above Crete to form the main Blue. It has a length of about 90 miles by general course from the head of the South Branch, and drains 1,357 square miles. Power is used by a considerable number of flouring-mills, of which I learned the locations of six to be as follows, in order from the mouth: West Mills, Beaver Crossing, Blue Valley, Fillmore, point 2 miles west of Fillmore, and Farmer's Valley. These mills were all said to have two runs of stone each, except that at Beaver Crossing, which has three runs. This stream is reported to be about 50 feet wide, and to have rather low banks, so that there is danger of flooding in high water.

The North Fork of the Big Blue rises in Hamilton county, within a few miles of the Platte. It runs easterly and then southerly, finally uniting with the West Fork. Its length by general course is about 80 miles, and its drainage area 1,326 square miles, or nearly the same as that of the West Fork. The surface of the country is similar to what has been so frequently described for neighboring streams. Brick-clay is found above Seward, but no timber or stone of consequence. The highest mill on the stream is a small one of two runs at Ulysses. There are doubtless available sites for power to be found above Seward, but the volume of the stream is said to be small at a low stage, and it is difficult to find firm foundations for dams. In the vicinity of Seward the North Fork is 50 to 75 feet wide at a mean stage. The bed is of mud, underlaid by clay; the banks are of loam, and 15 to 25 feet in height.

The next power used below Ulysses is at Seward. The dam is of brush, 75 feet long, and 8 feet high. It was built in 1868, and is stated to have cost $1,100. The pond sets back 3 miles. The wheel is of 35 horse-power, and runs under a head of 8 feet. The mill carries two runs of stone, and obtains sufficient water for running at full capacity nine to ten months in the year, and half capacity the remainder of the time. During the summer rise considerable trouble is experienced for two or three weeks from backwater. There is said to be a mill of three runs 1½ miles below Seward. The only other mill on the North Fork is at Milford, some 7 miles above the junction with the West Fork. The power is owned by Mr. J. H. Culver, who has in operation a flouring-mill with four runs of stone, and four rollers for the Washburn process, each set of rollers requiring about the same power as one run of

stones. About 150 horse-power of wheels are in use, and there is abundance of water for running at full capacity throughout the year. The dam is of brush, stone, and gravel, and was built in 1866 at a cost of $3,000. It is 178 feet long, 10 feet high, and gives a head of 10 feet on the wheels. The foundation is magnesian limestone. The pond is estimated to set back 7 miles, measured along the river's course, and to average 125 feet in width and 8 feet in depth. Mr. Culver states that, at Milford and below, the Blue is crossed by a magnificent belt of magnesian limestone, 5 miles in width, and that in this belt there are four good unimproved sites for power, at which heads of 9 feet can be secured. One of these was to be used, in the spring of 1881, for the manufacture of straw paper. Below the stone belt, to Beatrice, the river bed is said to be sandy, and less favorable for water-power sites. At Milford the North Blue has an average width of about 100 feet, running perhaps 8 inches deep at low water, and 6 to 8 feet at mean high water.

Lincoln creek joins the North Fork at Seward from the west. It is 64 miles long by general course, and is used for power by 1 or 2 small mills. The width near the mouth is about 50 feet, and the drainage area 447 square miles.

Tributaries of the Big Blue river.—Estimated volume and horse-power.

Stream.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Black Vermilion	533	30	34	40	45	50	57
Little Blue:							
At Ox Bow	951	60	68	90	102	100	114
Below Big Sandy	2,007	140	159	190	216	210	239
At Hanover	3,180	210	239	280	318	320	364
At mouth	3,461	220	250	310	352	350	398
Big Sandy creek *	505	30	34	50	57	60	68
Turkey creek	686	40	45	60	68	70	80
West Fork Blue	1,357	70	80	110	125	120	136
North Fork:							
Below Lincoln creek	1,090	60	68	90	102	100	114
Above West Fork	1,326	70	80	110	125	120	136
Lincoln creek	447	20	23	35	40	40	45

* Usually dry, except in high water, above a distance of 15 miles from the mouth.

THE REPUBLICAN RIVER.

Formed by a number of small forks which head in eastern and northeastern Colorado, the Republican enters Nebraska and flows more than half way across the southern part of that state, the main stream being nowhere more than 20 miles above the Kansas boundary. It finally enters the latter state, and, taking a southeasterly course, unites with the Smoky Hill to make up the Kansas river. Measured from the sources of the Arickaree and South Forks it has a length, by general course, of about 430 miles. The water-shed lines cannot be traced with accuracy upon any maps now in use, but probably include a drainage area of about 24,600 square miles. The country embraced is not essentially different in outward appearance from that drained by the Blues. As a whole, however, it is less fertile, and has not, perhaps, so much timber; in fact, the upper basin of the Republican has so small and uncertain a rainfall, and so light a soil, that it has little value for agriculture. In that section there are scarcely any settlements; but after the river has passed well to the eastward, in Nebraska, there are frequent small towns along its course, with a few hundred inhabitants each, and in Kansas it enters a comparatively well settled region. The larger towns on its course are Junction City, population, 2,700; Clay Center, 1,800; Clyde, 900; and Concordia, 1,900. The Burlington and Missouri River Railroad Company have been constructing a line to Denver, following up the Republican valley from Red Cloud, and early in 1881 it was in operation to Indianola, in Red Willow county.

The bed of the Republican river is at almost all points sand, and is to a great extent shifting quicksand of the most unstable character. In some localities it is underlaid at a moderate depth by limestone rock, and this even forms the immediate bed at a few places; but usually the bed is as above described, and evidently very unfavorable to the security of dams. The river is wide and rather shallow, with a rapid descent. It is subject to sudden rise and fall, and occasionally overflows in its lower course. It carries considerable drift, and is sometimes gorged by ice. Its upper waters extend to the basins of the Arkansas and Platte, and from the latter stream it is thought to receive underground drainage, just as do the Blues farther east. The sandy bed of the Republican is supposed to be continuous with a stratum of sand underlying the whole region and constituting the plane of drainage. Whenever wells are sunk to this plane water is reached. Under the bluffs it is, of course, deep below the surface, in proportion to their height, and I was told that south of the Platte, on the divide between that river and the Republican, a well was bored 230 feet before reaching this water-bearing stratum.

The principal rise in this river occurs early in June, from which time high water continues till about the 1st of August. During this period heavy and protracted storms occur, and the stream rises rapidly, to fall away in a day or two. After August 1 it sinks away quickly and reaches a low-water stage, which remains substantially the same till the next June rise.

Slope of the Republican river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Head of Rock creek†	4,050			
Western line of Nebraska†	3,600	450	60	7.50
Culbertson†	2,760	840	78	10.77
Indianola†	2,600	160	29	5.52
Arapahoe†	2,250	350	32	10.94
Orleans†	2,150	100	36	2.78
Concordia‡	1,384	766	148	5.18
Clyde§	1,287	97	19	
Clay Centre†	1,219	68	38	3.23
Gatesville§	1,158	61	13	
Mouth of river (water surface)	1,070	88	30	2.93

* Map measurement.
† Elevation given by Professor Aughey in *Physical Geography of Nebraska*.
‡ Elevation by Union Pacific railway levels (rails).
§ Elevation by Union Pacific railway levels (water surface).

NOTE.—There are such changes in the slope, according to the above table, that I can hardly believe all the figures reliable; still they will give some idea of the descent in different portions of the river.

Professor Aughey thus writes, in the *Physical Geography of Nebraska*, concerning one of the streams which go to make up the main Republican, and which he evidently regards as the principal source:

The Republican river rises in the Colorado plains, near range 49, west of the sixth principal meridian. Here, anciently, there was a lake, whose basin was about 4 miles across. The outlet, or river, draining it, however, long since cut down the narrow rim and drained the lake. Its head here in the old lake is 4,050 feet above the sea. A few small springs now rise below the site of this old lake, and produce a tiny streamlet, a foot across. Other streams, about or nearly as large, soon join it, but at the state line I could still, when there in the spring of 1877, jump across it. Along this part of its course there are a few beautiful little lakelets, into which and from which it flows. Here the water is cool and clear as crystal. When it receives the water of the Arickaree, about 7 miles east of the state line, it assumes its characteristic character.

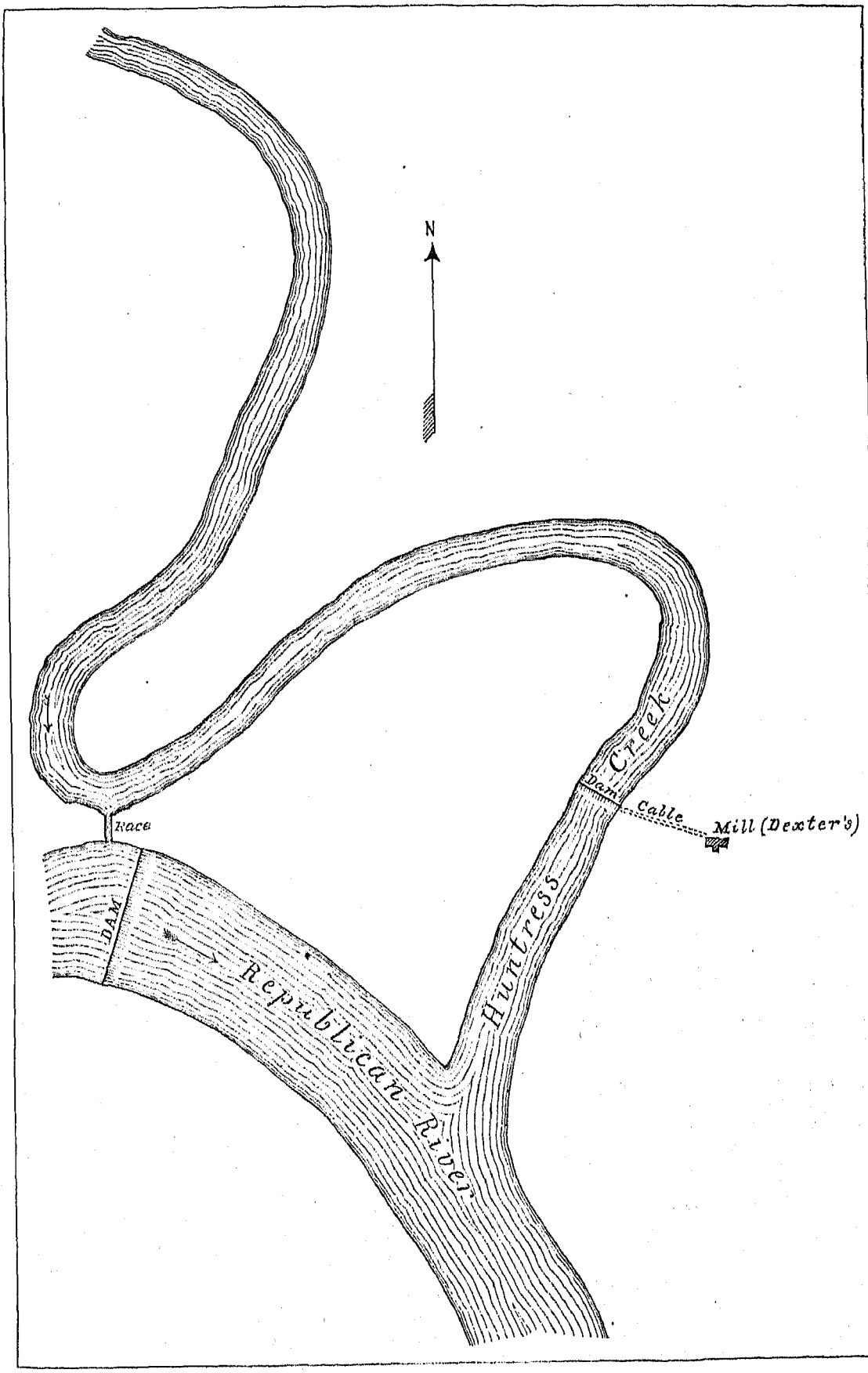
It now becomes shallow and sandy, and in places rapid. Its principal tributary in this portion of the state (Nebraska) is the Republican Fork, and comes from the southwest. Its junction with the Republican is in range 38 west. Frenchman's Fork (*a*) is an important tributary that rises in Colorado, and, flowing southeast, joins the Republican at Culbertson. After this the most important tributary from the southwest is the Beaver. Red Willow and Medicine creeks, from the northwest, are also important tributaries. An immense number of small creeks flow every few miles into the Republican, especially from the north. This river, unlike the Platte, increases regularly in breadth and volume all the way from its source to its exit from the state in Nuckolls county. It is forded in many places, and the only danger is from quicksands.

Toward its mouth the Republican is fringed with a moderate amount of timber, and runs with very winding course through a valley one-half to three-quarters of a mile wide. The banks are 5 to 10 feet high. The bed is sandy, and numerous bars and islands are to be seen. The first point at which power is used, in ascending the stream, is Clay Center, in Clay county, 30 miles or so by general course from the mouth. The river is here said to be 500 feet wide in high water, and 4 to 10 feet deep; while in a low stage the width scarcely includes 100 feet of running water. The current is very swift, and the flow reasonably steady from month to month. The bed is, to a considerable extent, quicksand. Mr. McLaughlin, deputy county surveyor, said that piles had been driven 14 feet into the sand, in founding bridge-piers, without reaching any solid foundation. The bed shows numerous sand-bars, and is very changeable. The banks are of loam, and usually about 10 feet high, but in places where the river cuts into the bluffs reach a height of 60 feet on one side, but are low on the opposite side.

The river has overflowed its banks in this locality twice during fifteen years, running at such times half a mile to a mile wide. The bottom-land is 1½ to 2 miles wide between the bluffs, which are quite low. A fair amount of timber is found in this section, principally ash, hickory, oak, cottonwood, elm, and white oak. Corn and wheat are the staple products, the bottom-land being best suited to the former. There is an abundance of blue and magnesian limestone, and sandstone both red and gray. The river is used only to a small extent for water-power, mainly from a lack of capital and the difficulty of maintaining dams.

In view of the latter fact it is interesting to note the experience of Mr. Dexter, proprietor of the privilege at Clay Center. He at first received great discouragement from the settlers there, and was assured that a structure

a Whiteman's Fork on the maps.



WATER PRIVILEGE AT CLAY CENTER.

could not be built which would withstand the river. He persevered, however, and succeeded in building a dam in which he has perfect confidence, and which he thinks it is practicable to duplicate at any point on the river.

The dam was built in 1865, is 450 feet long, and is estimated to have cost in all $30,000 to $40,000. The bed at this point is entirely of quicksand, and into this the dam has gradually sunk 15 to 30 feet; it is now believed to rest firmly on hard-pan, as shown by the material scoured up by the water below the dam. In building the structure large trees, 50 or 60, and even 100 feet long, were laid on the river bed, with their buts down stream. The spaces were filled with brush, and layers of brush and stone were added till the structure was complete. At first too small a proportion of brush was used, and the dam did not stand well, but a larger proportion was subsequently employed. There are no piles in the dam, and no vertical binders, but in construction the brush and branches of trees were entwined and entangled as much as possible. Some years ago a portion of the top of the dam was carried away on the breaking up of an ice-gorge. Constant repairs have been necessary, and immense amounts of stone have been hauled onto the dam, many stones weighing several tons each.

The structure is only 7 feet high at the center, but rises to 10 feet toward either shore, the object being to throw the current toward the center, and so avoid scour around the ends. The latter are higher even than the adjacent bottom-land, over which the river sometimes spreads, leaving the ends of the dam projecting above the water surface, like two islands. With this arrangement Mr. Dexter says there is no washing of the banks, and they are not otherwise protected. Toward the center, the permanent, substantial part of the dam is only 5 to 5½ feet high, and above this is 2 feet or so of light stone- and gravel-work, temporary in nature, and not firmly united to the rest of the dam. The design is that in a heavy rise this light work shall be carried away, making an enlarged water-way, and also tending to prevent scour around the ends of the dam. This plan will, the owner thinks, save the structure, and entail a damage of only $100 or so. The dam is probably 60 to 75 feet wide at the base, and below it an apron of brush and stone extends 75 to 100 feet down stream.

From the dam water passes 90 feet through a canal into Huntress creek, and thence to the mill, distant half a mile. Here a short dam has been thrown across the creek, and near one end of it the wheel is set, power being transferred by wire cable 150 or 200 feet to the mill. There is a head of 7 or 8 feet on the wheel, which is of 65 horse-power. The flouring-mill has four runs of stone, and no difficulty is experienced in running at full capacity throughout the year. The pond in the main river sets back some 4 miles along its course. Mr. Dexter is willing to rent the surplus power at his privilege. He states that he is never troubled more than a day or two by backwater. There is often a heavy run of ice in the river, but it does not usually gorge in this vicinity.

The next improved power on the river is at Concordia, in Cloud county. My information concerning this part of the river was given me by Mr. McCrary, county surveyor. He states that in a low stage there is a width of perhaps 160 feet of running water, with a depth of about 3 feet, the width of the river, measured between banks, averaging 450 feet. The bed is entirely of quicksand, and piles for bridge-piers do not reach the bottom of it, even at depths of 15 or 20 feet. The banks are of sandy soil, and range from 3 to 20 feet in height above low water. The bottom-land is 4 to 5 miles in width between bluffs, the latter rising to a height of 100 feet, more or less, above the river. The stream has a rapid current (4 or 5 miles per hour), and a fall of probably 4 to 5 feet per mile. The volume is quite uniform, from month to month, but is subject to sudden rise and fall after storms. The extreme rise noted is 16 feet. The river overflows its banks once in a few years, and spreads out to a width of half a mile or a mile. Local rains sometimes cause a rapid and considerable rise. Such a rain, along Buffalo creek, has been known to raise that stream to such a point that it, in turn, has carried the Republican over its banks. The channel of the river changes frequently, and along its course are more or less snags and sand-bars.

The chief productions of the surrounding country are corn and wheat. The timber has been largely cut away, but there is plenty of magnesian limestone suitable for building. It is thought that a mill privilege might be formed every few miles, and a head of 8 or 10 feet secured. There are occasional long bends or loops in the river, across the necks of which races might be cheaply cut, and advantage taken of the intermediate fall in the stream. There are said to be two such bends near Concordia. Lack of capital and the difficulty in maintaining dams are given as the reasons for non-improvement of the river.

The privilege at Concordia is occupied by LaDoue's flouring-mill. The dam rests upon a bed of quicksand 20 feet deep, underlaid by rock. Two dams, made of piles and sheet-piling, filled with stone and planked over, were successively carried away by high water and ice. The present structure was built in 1873, at a cost of $10,000, and is 420 feet long and 5 feet high. It is constructed of willow brush 12 to 18 feet long, tied with stout wire in bunches 6 or 8 inches in diameter; these are pinned down with long stakes and ballasted with sod, no rock being used in the dam. The entire height of the dam above the base is 21 or 22 feet, it having sunk 16 feet into the sandy bed. It has a width of 40 feet on top, and 50 to 60 feet at the bottom. It has no artificial abutments and no separate apron; the brush is laid, however, so as to give a sloping face, which serves to break the force of the water. The fall of water over the old dam caused a large hole, 16 feet deep, to be scoured out in the bed immediately below, but the effect of the new structure has been to fill up the hole by a back-wash, so that the water is now only 2 or 3 feet deep. There is a head of 5 feet on the wheel. The mill carries three runs of stone, utilizing 40 horse-power, for which there is an abundance of water at all times, with no trouble from backwater. The water-wheel is located at one end of the dam, and power transferred to the mill by a shaft 100 feet or more in length.

The only mill above Concordia, in Kansas, is at Scandia, in Republic county. Entering Nebraska we find mills at the following points, in order: Superior, one mill of three or four runs; Guide Rock, one mill of two runs, not in operation; 1½ miles west of Red Cloud, one mill of three runs; one mill of three runs in Franklin county; one of two runs at Orleans, and one mill of four runs at Arapahoe, in Furnas county. The dams at these places are said to range from 250 to 400 feet in length, and from 8 to 15 feet in height. They are said to be mostly framed structures, and, according to the nature of the bed, are built either of bents bolted down to rock, or of piles surmounted by capping-pieces and planking, the whole backed by brush and other material. The power at Red Cloud is used by the flouring-mill of Messrs. Potter & Frisby. They have a timber dam, which was built in 1875 and cost about $4,000. It is 350 feet long, 5 feet high, and is in the form of a half-circle, having its crest immediately supported by 9-inch piles, driven at intervals of 7 feet through the sandy bed to the limestone rock which underlies it. The crest is shod with iron straps to prevent injury by ice and drift. The fall at the dam is 5 feet, and the mill has three runs of stone, with water-wheels of 50 horse-power. A small saw-mill is run in connection with the same power. The owners of this privilege say that there is an abundance of water at all seasons for their use, and a considerable surplus. Slight trouble is experienced with anchor ice in the fall, and for about one week in the year with backwater.

The river in this vicinity is, at mean low water, 80 feet wide and 2 feet deep; at mean high water the average width is about 420 feet, and the depth is perhaps 4 feet. The current is very swift, and the fall rapid. I was informed by Mr. Strohm, county surveyor, that the fall near Red Cloud is 14 feet per mile, and that 28 miles to the west he had found it 15.6 feet per mile. Another gentleman gave the average fall of the river through the county as 7 feet 8 inches to the mile. The flow is said to be quite steady, the river seldom overflowing its banks and not being much affected by any but very heavy or protracted storms. Heavy masses of flood-wood float down stream at times. During heavy runs of ice, gorges occasionally form and cause a set-back in the river, and in one instance, at least, have resulted in a submergence of the banks. The channel shifts frequently. The bed is occasionally a magnesian limestone ledge, but in general is a kind of quicksand, about 10 feet deep, extending out in a uniform plane under the surrounding country. The banks are usually of loam, and are 5 to 6 feet in height; in some places, however, where the river cuts into the bluffs, they are much higher on one side.

The bluffs average about 75 feet in height, and inclose between them about 3 miles in width of bottom-land, of which 1½ miles belongs to the lower or "first" bottom. The surrounding country is open and rolling. The main stream and its tributaries are fringed with a moderate amount of timber, comprising cottonwood, elm, ash, box-elder, and walnut. Corn, wheat, and other grains are raised. The soil is good, but the climate is rather dry, and in some years the crops are very small.

I believe there are no long-continued records of rainfall for points within the Republican basin. Judging, however, from the Smithsonian tables, I should estimate the precipitation to be about as follows:

1. For the lower river: Spring, 6.5 inches; summer, 10.5; autumn, 5.5; winter, 2; year, 24.5.
2. For the upper basin (above Indianola): Spring, 4 inches; summer, 5; autumn, 3; winter, 1; year, 13.
3. For the entire basin: Spring, 6 inches; summer, 8; autumn, 4; winter, 1.3; year, 19.3.

I cannot learn that any measurement has ever been made of the volume of the river, except one by Professor Aughey, in July, 1876, which showed a discharge of 1,638 cubic feet per second (*a*) at the boundary between Nebraska and Kansas; but the river was probably much above its low-water stage at that time. I estimate roughly the volume and theoretical horse-power of the stream as in the accompanying table:

Estimated volume and horse-power of the Republican river.

Locality.	Drainage area.	Low water, ordinarily dry year.		Low water, average year.		Available 10 months in average year.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Indianola	12,884	200	230	350	400	430	490
Below Beaver creek	19,263	400	450	650	740	800	910
Bloomington	20,073	430	490	710	810	870	990
Red Cloud	21,503	450	510	730	830	890	1,010
Kansas boundary	22,085	530	600	800	910	970	1,100
Concordia	23,253	590	670	890	1,010	1,080	1,230
Clay Center	24,227	700	800	980	1,110	1,190	1,350
Mouth of river	24,587	725	825	1,000	1,140	1,230	1,400

TRIBUTARIES OF THE REPUBLICAN RIVER.—Regarding the tributaries of the Republican, I have but little information. Buffalo creek enters the main stream from the west, a short distance above Concordia, and is reported

a 0.074 cubic foot per second per square mile of drainage area.

to have one mill at Jamestown, with a stone dam 16 feet high. The other little streams in that section would carry small powers for part of the year. White Rock creek, which joins the Republican from the west not long after it enters Kansas, drains 387 square miles. It has high banks, rock ledges in its bed, and a well-sustained volume, but is subject to heavy rise and overflow. It is used for power by two small mills.

Of the tributaries received in Nebraska, Turkey creek has one mill in Franklin county. Prairie Dog creek comes from the southwest, and lies mainly in Kansas. It drains 1,021 square miles, and is used for power by half a dozen flouring-mills. Beaver and Sappa creeks drain long, narrow strips in northwestern Kansas, and unite shortly before they reach the Republican in Nebraska. They are improved by one or two small mills, and are said to be very good streams for power, especially Beaver creek. They have a combined drainage area, at the junction with the Republican, of 4,050 square miles, while Sappa creek alone drains 1,740 square miles. Frenchman's Fork has an 18-foot fall over rock, and Red Willow, Indian, Elm, and Farmer creeks are all reported to be suited to small powers.

I secured no information about the other tributaries of the Republican, but all those which I have mentioned could probably be relied upon throughout the year for powers of moderate size. It is said that none of them ever run dry; on the other hand, they are well sustained in flow, have a good fall, and favorable beds. They rise and fall rapidly during summer rains, and in some cases overflow the bottom-lands widely.

THE SMOKY HILL RIVER.

This stream, the last tributary of the Kansas river to be described, rises near the boundary between Kansas and Colorado, whence it pursues a winding, but on the whole easterly, course through Kansas, till in Davis county it unites with the Republican. It has a length by general course of 310 miles, and a total drainage area of about 20,000 square miles. East of Salina the river is a constant succession of bends, and in Dickinson county its actual length is at least twice as great as the distance by general course. The only important tributaries are the Saline and the Solomon, which enter the lower river from the north, their courses, however, being in the main parallel to the Smoky Hill.

The Kansas Pacific railway follows the latter river from its mouth to Salina, strikes it next at Fort Harker, and finally at Wallace, near the headwaters. Along the line of this road, where it borders the river, are a number of enterprising towns, of which the most important are Junction City, at the mouth of the river, population, 2,700; Abilene, 2,400; Solomon City, 600; Salina, 3,100; and Ellsworth, 900.

Slope of the Smoky Hill river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Wallace†§	3,345	1,815	211	8.60
Ellsworth‡	1,530	210	56	3.75
Lindsborg‡	1,320	130	38	3.42
Mouth of Saline‡	1,190	24	13	1.85
Mouth of Solomon‡	1,166	96	77	1.25
Mouth of Smoky Hill§	1,070			

* Map measurement.
† Rails, Kansas Pacific railway.
‡ Kansas Pacific railway levels, water surface.
§ Water surface.

The Smoky Hill river is distinguished by a sandy bed, rapid fall, and variable flow. Its volume is at certain seasons very small, and in the upper course it is for much of the time entirely dry.

The first power met in ascending the river is at Junction City, and but a short distance above the mouth. At the site of the dam the river bed contains a rock ledge, dipping from the surface on one side to a depth of 15 feet beneath the surface on the other. Overlying this rock is sand, and upon this the dam rests most of the way. It is a framed structure, abutting against the mill foundations at one end and against a crib filled with stone at the other. It is 160 to 175 feet long, 9 feet high, and was built in 1864. Above the dam the river bed is covered with stone, and below it an apron is formed by timber and stone crib-work. The pond sets back 6 or 7 miles. A wheel of about 60 horse-power runs under a head of 9 feet, and supplies the mill with power for four runs of stone. There is always a large surplus of water, and the owner even estimates his privilege to be good for 500 horse-power throughout the year. He claims to have no trouble from ice or backwater.

In this portion of its course the Smoky Hill has a size, at mean low water, of 130 to 160 feet by 3 feet; in mean high water it is 175 feet wide and 15 to 18 feet deep. The current is strong at all times, and during high water is very swift. The bed is of ordinary sand or quicksand, and shows rock ledges in the shoals. The banks are sandy, and

10 to 12 feet in height. Black walnut, hackberry, oak, and other varieties of timber fringe the side streams, about 5 per cent. of the surface of Davis county being wooded. The bottom-land is 1 mile to 2½ miles in width, and bordered by low bluffs. The bottoms yield large crops of corn, but on the uplands wheat is more generally raised. Magnesian limestone is found in abundance. It was stated to me that there are fine sites on this part of the river, unimproved for lack of capital, and that custom mills are very much needed. The present mills do a large business, and find so ready a sale for their flour in Colorado and Texas that they do not undertake much custom business.

At Enterprise there is a fine flouring-mill with four runs of stone, followed by mills at Abilene and Salina. The dam at the latter point rests upon a quicksand bed, and consists of a mass of loose rock, packed as closely as possible and surmounted by a low framed structure. It is obtuse-angled in plan, the vertex being up stream, of course, and abuts at each end upon timber cribs, one filled with stone and the other with clay. The river banks are protected by rip-rap below the dam. The mill uses a head of 8 feet, and has five runs of stone. There is trouble here for about two weeks in the year from backwater.

At Salina the Smoky Hill is, in mean low water, about 40 feet wide and 2 feet deep; in high water it is 150 feet wide and perhaps 25 feet deep. The bed is composed, at various points, of firm sand, quicksand, gravel, and occasionally sandstone or limestone ledges. The banks are of loam, 25 feet high, and are seldom overflowed to much extent. High water occurs in June, but may come at any other time, as it results from rains, and not from the melting of snow, the amount of which is small in the Smoky Hill basin. There is a fair amount of timber bordering this part of the stream, mostly cottonwood, with some hackberry, box-elder, and elm. Plenty of fine building-stone is found, comprising blue limestone, gypsum, and red and gray sandstones.

There is reported to be a good unimproved site for power 2 or 3 miles below Salina, where a head of 7 feet could be secured. There are two or three mills on the Smoky Hill above Salina, but I am unable to give their location.

Above Ellsworth, distant from the river's mouth about 100 miles by general course, this stream has little or no value for power on account of its sandy bed and small volume, which sometimes entirely disappears during the warm season. At Ellsworth the Smoky Hill is, at a mean low stage, 50 to 75 feet wide and 1 foot deep; at mean high water it is about twice as wide, and in the highest known rise has attained a depth of 20 to 23 feet. It occasionally overflows in places, and because of its exposure to such accidents the village of Ellsworth was removed to its present position from a point 1 mile farther down stream. The river bed is in this locality mostly a firm sand, and the banks are of clay and sandy loam, 10 to 15 feet in height. The valley is three-quarters of a mile to a mile and a half in width, and exhibits a gradual rise on the north side, without bluffs. At Wilson, 10 miles above Ellsworth, there are bluffs 125 feet high on the south side of the valley.

Opposite Russell, 35 miles westerly from Ellsworth, the river is at mean low water about 60 feet wide and 6 inches deep; and at mean high water about 160 feet wide, with a depth of 7 feet. The valley is 1½ to 2½ miles in width, and is bordered by bluffs 180 to 200 feet high. The river bed is of quicksand. For 3 feet in depth it has a light color, but lower down is a very sharp, black sand. A great deal of magnesian limestone is found in this region, and in Russell I saw buildings constructed of bricks of that material. The bricks were of the ordinary size, sawed out of the limestone, and said to be furnished at $7 per thousand.

The last point visited was Hays City, which is about 12 miles north of the main river. In this locality, not more than midway between the mouth of the river and its extreme source (*a*) on the Colorado line, and with a drainage area above of 6,000 square miles, the Smoky Hill has a size in mean low water of about 10 feet by 4 inches; and this size is seldom much exceeded, except temporarily after a heavy storm. It frequently disappears entirely in its bed of quicksand during summer, especially if there has been but little snow during the preceding winter. There is usually a moderate current of about 3 miles an hour. The stream is clear, and is subject to rapid oscillations after storms, never rising, however, more than 5 or 6 feet. The banks are sandy and low, and in some places the river submerges the first bottom, but this is very narrow. Above Hays no timber whatever is found on the Smoky Hill, and none worth mentioning on any of its tributaries.

The river valley is in this vicinity about 3 miles wide between the bluffs, but of this distance not more than half a mile is level ground, the remainder being a gradual or broken rise. The country drained has a good soil, but insufficient rain. Considerable wheat and corn is raised, and the crops are generally good, but yet failures are not uncommon. The wheat crop was a failure in both 1879 and 1880. A gentleman who has lived at Hays ten or fifteen years says there has been no observed increase in the annual rainfall in that section, in the size of small streams, or in the number of springs; but still he thinks the rains are somewhat less violent and are better distributed than formerly, and that the average humidity of the atmosphere is greater. As an evidence of the natural fertility of the soil, he states that when there is abundant rain vegetation grows with great luxuriance. As we advance westward the soil grows lighter, and near the Colorado line probably is of little value.

The surrounding country contains plenty of ordinary and magnesian limestones, and bituminous coal of an inferior quality is found in Russell county. In Ellis and Trego counties there are immense deposits of pure white chalk in the bluffs along the Smoky Hill. In Trego county there are also beds of a very fine sand, said to be valuable for polishing machinery.

a Probably for flood drainage only.

From the Smithsonian tables I estimate the average rainfall on the Smoky Hill basin as follows: Above Hays, spring, 5.7 inches; summer, 5.6; autumn, 4.9; winter, 2.6; year, 18.8; for the entire basin, spring, 5.6 inches; summer, 7.2; autumn, 5.2; winter, 2.6; year, 20.6. In the absence of any gaugings I estimate the discharge of the river as in the table below:

Estimated volume and horse-power of the Smoky Hill river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Below Saline river	11,041	190	216	270	307	380	432
Below Solomon river	18,859	380	432	530	602	720	818
At mouth	20,144	400	454	560	636	750	852

TRIBUTARIES OF THE SMOKY HILL.—In the lower course are received Lyon's, Chapman's, and Turkey creeks, all small streams, but used to a slight extent for power by flouring- and grist-mills. At Hays City, Big creek, which has a drainage area of 740 square miles, is improved for power by one mill; this obtains a head of 24 feet, and sufficient water to carry two runs of stone half the year. The only important tributaries of the Smoky Hill are the Solomon and the Saline.

The Solomon river.—Two forks, heading in the northwestern part of Kansas, unite in Mitchell county to form the Solomon river. The North Fork starts from the northeastern part of Thomas county, and makes a curve to the northward; it has a length by general course of 134 miles, and a drainage area of 2,631 square miles. The South Fork rises in the southwestern part of Thomas county, and pursues an easterly course. The length of this fork is 160 miles, and it drains 2,415 square miles. From the junction of these two forks the Solomon follows a southeasterly course for about 77 miles, till it empties into the Smoky Hill at Solomon City. It receives no important tributaries except the two forks already mentioned, and comprises within its basin 6,939 square miles.

Slope of the Solomon river.

Locality.	Elevation above sea.	Fall between points.	Distance between points.*	Fall between points.
	Feet.	*Feet.*	*Miles.*	*Ft. per mile.*
Kirwin, North Fork†	1,718			
Bulls City, South Fork†	1,673	91	19	4.79
Osborne, South Fork†	1,582	110	19	5.79
Cawker†	1,472	71	27	2.63
Beloit†	1,401	47	14	3.36
Brittsville†	1,354	104	27	3.85
Minneapolis‡	1,250	84	35	2.40
Mouth of river§	1,166			

*Map measurement.
†Railroad levels, elevation of rails.
‡Water surface in Pipe creek at railroad crossing.
§Water surface at Union Pacific crossing.
NOTE.—Those slopes which are based upon comparisons of elevations of rails are obviously liable to some error.

In ascending the river the first improved power is at Bennington, where there is a three-run flouring-mill having a brush dam. The next power is at Minneapolis, county seat of Ottawa county, a place of some 1,100 inhabitants. The dam is of brush, and rests upon a sandstone bed; it has an artificial stone abutment at one end, and at the other abuts against a rocky bluff. In its construction a layer of trees, having their branches on, was first placed on the bed of the stream. The trees were laid side by side, parallel to the course of the stream, and were packed as closely together as possible, their buts pointing down stream. Upon this layer, which was perhaps 4 feet deep, a 4-foot layer of brush was added. An oak log was then placed on the brush, running transversely and several feet back from the ends of the trees, thus leaving their buts projecting a little way for an apron. Long spars, running up stream, were now dovetailed to the transverse log, and upon top of all loose rock was piled as

thickly as possible. There were then added successively a 4-foot layer of brush, a transverse log, and spars, as before. The top was next filled with rock to a regular incline, and planked over for a distance of 30 feet back from the crest.

The owner puts the cost of the structure at only $700. It was built in 1875, and is 100 feet long, with a fall of 8 feet; it stands well, and is reasonably tight. Before this dam was built a log dam was in use, but did not stand successfully. The pond extends 3 miles up stream. There is a head of 8 feet on the wheel, which gives power for three runs of stone. Water is brought to the wheel through a tunnel excavated in the rock, 80 feet long and 6 by 4 feet in cross-section. A separate tunnel, 1,000 feet long, conveys water to run two elevators (about 12,000 and 20,000 bushels capacity), and a pump for the railroad water-tank. There is always a surplus of water at this privilege, and for one to four weeks trouble is experienced from backwater. The owner estimates that with the present dam six runs of stone could be carried in the lowest stage of river.

The river in this part of its course is about 150 feet wide, with a depth varying from 4 feet at ordinary low water to 12 or 15 feet at high water. It has a moderate current and a steady flow. The period of high water extends from April to the 1st of August, the highest stage occurring for a few days during the heavy June rains. Once in a few years the main river overflows the bottoms in places, or else by its backwater compels the tributary creeks to run over their banks, in low spots, and so accomplish the same result. Owing to its tortuous course and rather moderate slope, local storms on the river above are not felt for some days at Minneapolis; and it is said to take one to two days for high water to extend from Delphos to that point, a distance of only 10 miles in a straight line.

The bed is mostly sand, but there are some riffles over rock ledges. The banks are of loam and are of fair height; at Minneapolis the river comes up to a bluff, and one bank rises abruptly 20 or 30 feet. The valley narrows at this point to 2 miles, but widens, a short distance below, to 4 miles. The bluffs probably average 125 feet in height above the river, though in places they almost disappear and there is seen only a wide level or gently inclined surface. The valley and surrounding country are good wheat and corn lands, the bottom being rather the best adapted to corn. There is an abundance of good building-stone, comprising magnesian limestone and sandstone, of red and darker shades. Along the main river and its small tributaries are found moderate amounts of timber—cottonwood, oak, elm, hackberry, and black walnut. There is a large amount of power still undeveloped on this part of the river. I was informed by Mr. Crosby, of Minneapolis, formerly county surveyor, that there are two good unimproved sites between Minneapolis and Delphos and one betwen Minneapolis and Bennington. There is a rock bed at all these places, and heads of 10 or 12 feet can be secured.

Above Minneapolis there are mills on the Solomon at Delphos, Brittsville, Asherville, Libertyville, Beloit, Solomon Rapids, Glen Elder, and Cawker. The dam at Beloit was built in 1875, and cost $5,000. It is about 200 feet long including abutments, 10 feet high, and consists of V-shaped bents of timber, joined by cross-timbers fitted or spiked to them, all crevices being filled with loose stone carefully rammed into place. The pond sets back 5 or 6 miles up stream. The mill has a head of 10 feet, six runs of stone, and uses about 80 horse-power. The river is in this locality about 150 feet wide, 6 inches deep at low water, and 16 to 18 feet deep at mean high water. It occasionally overflows its banks and runs a quarter of a mile in width. In very cold winters it freezes so thickly that the volume of running water is much reduced.

The current in this part of the river is rapid, and the flow comparatively steady from month to month. The bed contains frequent ledges of soft limestone. The banks are of loam, usually high on one side and rather low on the other. The bottom-lands display successive flood-plains, sometimes four in number, and are bordered by low bluffs. Wheat and corn are raised in this section, but the crops, especially of wheat, are rather poor from lack of rain. Good limestone occurs, and is largely employed in building. It is of a yellowish tint, is easily quarried with crow-bars in blocks 6 to 12 inches thick, and shows a dark band, 2 to 4 inches wide, of the color of iron-rust, running through the center of each layer. The dams in this section of the river are said to be generally of crib-work—logs laid with the stream, cross-logs jointed or bolted to them, and the spaces filled with stone and brush. They have commonly a fall of about 10 feet. There are several mills on the main river in Mitchell county, but there are also reported to be good sites still unimproved.

At Cawker, a short distance below the junction of the North and South Forks, there is a two-run flouring- and grist-mill, using a fall of 9 feet and 30 horse-power. The dam is leaky, but the owner thinks his privilege would carry one more run as it now stands, in the lowest stage of river. His dam is a timber structure, built in 1871, and is 150 feet long and 9 feet high. The pond sets back for 3 miles.

The only tributaries of the Solomon of any importance for power are the two forks already referred to.

The first mill met on the North Fork is about 3 miles above Cawker. The wheel is of 40 horse-power, and runs under a head of 10 feet. The mill carries three runs of stone and has a surplus of water at all times. The dam was built in 1878, and cost $1,600. It is 98 feet long, 10 feet high, and consists of a timber crib-work packed with stone. It backs the water for about 1½ miles. As nearly as I could ascertain at Cawker there are mills beyond at the following points: 15 miles above Cawker, one mill; 18 miles beyond Cawker, one mill; one mill at Harlan and one at Cedarville, each two runs; one at Kirwin, one at Logan, and another at an intermediate point, each of three runs. There are also one or two mills still farther up stream. These mills are said generally to have dams built of logs, with brush filling, and to obtain heads ranging from 10 to 20 feet.

This stream is said to have a fall in its upper waters of 6½ to 8 feet per mile, and it was stated to me that a good, available site for power, with rock bottom, could probably be found, on the average, once in 3 miles. The North Fork averages about 70 feet in width toward the mouth. Its bed is largely composed of sand and gravel, with frequent limestone and slaty ledges. Where the latter occur below a dam they are badly torn up by the overflowing water unless protected, as they usually are, by an apron. The river banks are frequently high on one side and low on the other. The banks, where low, are composed of loam, but, where high and bluffy, stone usually crops out. In this case the rock often appears to run out under the stream and then to suddenly drop away. At the mill 3 miles above Cawker the wheel rests upon a hard and firm clay bottom, but 6 inches away from the wheel-pit, toward the stream, there is a wall of slaty rock belonging to the bluff on the opposite side of the river. The owner of this privilege has noticed similar occurrences elsewhere along the stream. The slate rock has no value for building purposes, being soft and crumbly.

The South Fork is about 50 feet wide at Osborne. It has a rapid current, and comparatively steady flow from month to month, but is subject to rapid oscillations after heavy rains. The highest stage is usually in the first week of June, when the stream regularly overflows its banks and runs one-eighth of a mile in width in its lower course. The bed is mainly sand and gravel and shows very little rock. The banks are of sandy loam, averaging perhaps 6 feet in height. The bottom-land is 3 to 5 miles wide between bluffs, the latter ranging from 75 to 200 feet in height. Both the bottom-land and the surrounding country are claimed to have a fertile soil, best suited by nature to wheat; but, owing to the scarcity of rain, corn is the principal crop raised. There is very little timber, only 2 per cent. of Osborne county being thus covered, and that is found fringing the streams. Plenty of good magnesian limestone is to be obtained in the bluffs, easily quarried, sawed, and planed, but growing hard on exposure.

The lowest mill on the stream is at Osborne. It carries four runs of stone, has 12 feet head, and there is said to be in process of construction a substantial stone dam, to cost $4,000 to $5,000. Above Osborne there are reported to be two mills, of two runs each, at Bulls City, and another mill of the same size at Stockton. The dams are described as costing from $1,000 to $3,000 each, and built of crib-work filled with brush. They are said to rest upon poor foundations, to be loosely constructed, and to give considerable trouble.

Estimated volume and horse-power of the Solomon river and its tributaries.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
North Fork:	*Sq. miles.*						
At Logan	783	15	17	25	28	30	34
At Kirwin*	1,553	35	40	50	57	60	68
At Eagle Rapids	2,210	50	57	70	80	90	102
At mouth	2,631	60	68	80	91	110	125
South Fork:							
At Beech creek	738	15	17	25	28	30	34
At Stockton	1,582	35	40	50	57	60	68
At mouth	2,415	50	57	80	91	100	114
Solomon:							
At Cawker	5,046	120	136	160	182	210	239
At Beloit	5,545	140	159	190	216	240	273
At Minneapolis	6,150	160	182	220	250	280	318
At mouth	6,939	200	227	260	295	330	375

*Below Deer creek.

The Saline river.—The Saline river rises in Wallace county, in northwestern Kansas, and flows easterly, parallel to the Smoky Hill, into which it finally empties. Receiving no important tributaries, it drains a long and narrow strip, which, until the river has run half its course, does not exceed 18 miles in width. The stream is not touched by any railroad except at its mouth, but it is only 5 to 20 miles distant from the Kansas Pacific line throughout its course. There are no towns of importance on the river. The Saline is 220 miles long by general course, and drains 3,463 square miles.

The country along this stream is fertile, and produces good crops of wheat and corn, the bottoms being rather the best adapted to the latter crop. On that portion of the stream lying above Russell there is considerable timber, including cottonwood, elm, ash, box-elder, and some oak and hackberry. Light sandstone is found on the Saline north of Russell, east of that blue limestone, 6 miles east of the locality first mentioned hard iron-stone, and farther

down stream blue limestone again. In the middle course the valley is 1 mile to 2 miles wide, and bounded by bluffs 200 feet in height. Toward the mouth the width of the valley increases to from 3 to 3½ miles, and the soil is said to be very rich, better, in fact, than that along the Smoky Hill.

North of Russell the river falls 22 feet in 3½ miles; from Lincoln Centre to the mouth, a distance, by map measurement, of about 48 miles, a railroad survey shows an approximate fall of 152 feet, or 3.17 feet per mile. If the river were accurately measured through all its windings the distance would appear much greater, and the slope correspondingly less. Thus I was informed by Mr. Rossiter, civil engineer, who had just finished a survey bordering part of the river, that, running 16 miles northwest from Salina, in a comparatively straight line along the stream, the actual length of river, following all its bends, was 96 miles. North of Russell the Saline is about 25 feet wide at low water and 3 feet deep; in a high stage it is 130 feet wide and 8 feet deep. It has a strong current and a bed composed of firm sand to a depth of 2 feet, below which it is blue clay. The banks are of sandy loam, and average 8 feet in height. In its lower course the river continues narrow, and below Lincoln is frequently only 25 to 30 feet in width. The bed in this section, and for a considerable distance above, consists mainly of quicksand. The banks are abrupt and high, usually 30 to 35 feet above low water.

Toward the headwaters of the river there are numerous beautiful pools of water, containing 1 acre to 7 acres each. The stream continues fresh till about opposite Russell, where the drainage from salt springs and salt marshes renders its waters strongly saline. It is said to be subject to an unexplained swell, continuing from the first of February till the middle of April. It is claimed that there is not enough snow at the headwaters to cause this rise, which is announced by the banks becoming wet and marshy. Whether or not it is due to underground drainage remains to be determined. The Saline has a steady flow from month to month, and is not greatly affected by ordinary storms; still, the heavy summer rains do produce important oscillations in its volume, and at some points it overflows its banks for perhaps 50 yards on either side. In its upper and middle portions it has a strong current, but toward the mouth it grows sluggish, and its slow current and crooked course tend to hold back high water, so that the stream does not run out very quickly.

Notwithstanding its generally sandy bed, the Saline shows some rock ledges in its course, and because of its reliable flow is looked upon as a good mill-stream. There are plenty of sites still unimproved. Ascending the stream, there are flouring- and grist-mills at the following points: Windsor, Rocky Hill, Lincoln Centre, Sylvan Grove, Paradise, and Martin. They carry from two to three runs of stone each, have in most cases heads of 8 to 12 feet, and are seldom short of water.

Bradshaw's mill, in Paradise township, has three runs of stone, with sufficient power for five runs, except in very cold winters, when the stream freezes almost solid and there is scarcely power for a single run. The mill is located about midway across the neck of a loop or bend in the river, the distance around the bend being 3½ miles. A dam has been thrown across the stream on the upper side of the bend, and a race carried across the neck, thus taking advantage of the intervening fall. A total head of 22 feet is thus obtained. The dam rests upon a gravel bed, and is built of brush; it is 90 feet long, 6 feet high, and was constructed in 1879 at a cost of $200. The original dam was only 60 feet long, but the river washed across one end, and the present structure was made longer. The banks are rip-rapped to prevent scour. The dam throws the water back about 1½ miles up the river.

Estimated volume and horse-power of the Saline river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Martin	1,200	25	28	40	45	50	57
Lincoln	2,560	60	68	90	102	110	125
Mouth of river	3,463	100	114	130	148	160	182

Power used on the Kansas river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Horse-power of wheels.
						Feet.	
Kansas	Missouri	Kansas	Douglas	Flour and grist	4	Lawrence power, 8 feet head.	265
Do	do	do	do	Iron castings	1		30
Do	do	do	do	Woolen	1		10
Do	do	do	do	Wire	3		9
Do	do	do	do	Shirt-factory	1		3
					9	8	317
Big Stranger	Kansas	do	Leavenworth	Flour and grist	2	31	85
Delaware	do	do	Jefferson	do	5	46	360
Do	do	do	Atchison	do	2	18	77
Straight	Delaware	do	Jackson	do	1		12
Cross	Kansas	do	Shawnee	do	1	9	24
Mill	do	do	Wabaunsee	do	2	17	60
Red Vermillion	do	do	Pottawatomie	do	2	20	56
Rock	do	do	do	do	1	12	60
Big Blue	do	do	do	do	2	17	85
Do	do	do	Marshall	do	1	Blue Rapids, head 8 to 11 feet.	105
Do	do	do	do	Paper	1		45
Do	do	do	do	Iron castings	1		12
Do	do	do	do	Plaster	1		30
Do	do	do	do	Woolen	1		125
Do	do	do	do	Saw	1	8	30
Do	do	do	do	Flour and grist	3	25	255
Do	do	Nebraska	Gage	do	4	32	255
Do	do	do	Saline	do	1	10	80
Fancy	Big Blue	Kansas	Riley	do	1	14	30
East Fork	do	do	Marshall	do	1	12	65
Little Blue	do	do	do	do	2	12½	175
Do	do	do	Washington	do	1	8	32
Do	do	Nebraska	Jefferson	do	3	23	140
Do	do	do	Thayer	do	2	13	85
Do	do	do	Nuckolls	do	2	15	110
Do	do	do	Clay	do	2	16	50
Do	do	do	Adams	do	1	10	30
Mill	Little Blue	Kansas	Washington	do	2	20	36
Rose	do	Nebraska	Jefferson	do	1	10	24
Do	do	do	Thayer	do	1	11	22
Spring brook	do	do	do	do	1	12	15
Big Sandy	do	do	do	do	1	8	60
Turkey	Big Blue	do	Saline	do	3	30	132
West Fork Blue	do	do	Seward	do	3	27	138
Do	do	do	Fillmore	do	1	11	48
Do	do	do	York	do	3	28	135
Do	do	do	Hamilton	do	1	14	19
North Fork Blue	do	do	Seward	do	3	25	212
Do	do	do	Butler	do	1	10	30
Lincoln	North Fork Blue	do	Seward	do	1	12	14
Do	do	do	York	do	1	12	20
Clark's creek	Kansas	Kansas	Davis	do	1	8	14
Smoky Hill	do	do	do	do	1	9	66
Do	do	do	Dickinson	do	2	18	222
Do	do	do	Saline	do	1	8	75
Do	do	do	McPherson	do	2	16½	44
Do	do	do	Russell	do	1	8	35
Lyon's creek	Smoky Hill	do	Dickinson	do	1	15	25
Chapman's creek	do	do	do	do	3	33	134
Turkey creek	do	do	do	do	1	9	35
Solomon	do	do	Ottawa	do	3	26	177
Do	do	do	Cloud	do	1	12	60
Do	do	do	Mitchell	Flour and grist (one saw)	7	60½	420
North Fork Solomon	Solomon	do	Smith	Flour and grist	2	23	75
Do	do	do	Phillips	do	3	29	112
Do	do	do	Norton	do	3	52	111
South Fork Solomon	do	do	Osborne	Flour and grist (and saw)	2	17	114
Saline	Smoky Hill	do	Lincoln	Flour and grist	4	42	127
Do	do	do	Russell	do	1	21	46
Do	do	do	Ellis	do	1	9	26
Big creek	do	do	do	do	1	18	36
Republican	Kansas	do	Clay	do	1	8	65
Do	do	do	Cloud	do	1	5	40

Power used on the Kansas river and tributaries—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Horse-power of wheels.
						Feet.	
Republican	Kansas	Kansas	Republic	Flour and grist	1	5	60
Do	do	Nebraska	Webster	Flour and grist (and saw).	1	5	75
Do	do	do	Franklin	Flour and grist	1	4	50
Do	do	do	Harlan	do	1	5	30
Do	do	do	Furnas	Saw	1	11	36
White Rock	Republican	Kansas	Republic	Flour and grist	1	10	30
Do	do	do	Jewell	Flour and grist (and saw).	1	12	50
Lost creek	do	Nebraska	Nuckolls	Flour and grist	1	13	65
Elm Creek	do	do	Webster	do	1	16	28
Turkey creek	do	do	Franklin	do	1	20	40
Thompson	do	do	do	do	2	26	90
Prairie Dog	do	do	Harlan	do	2	25	54
Do	do	do	do	Saw	1	12	30
Do	do	Kansas	Phillips	Flour and grist	1	12	35
Do	do	do	Norton	do	1	12	18
Do	do	do	do	Saw	1	10	15
Sappa	do	Nebraska	Harlan	Flour and grist	1	6	14
Do	do	Kansas	Norton	do	1	15	25
Beaver	Sappa	Nebraska	Furnas	do	1	15½	43
Muddy	Republican	do	do	Saw and grist	1	13	40
Medicine	do	do	do	Saw	1	8	24
SUMMARY.							
Kansas	Missouri	Kansas			9	8	317
Delaware	Kansas	do			7	61	377
Big Blue	do	Kansas and Nebraska.			16	103	1,022
Little Blue	Big Blue	do			13	103½	637
West Fork Blue	do	Nebraska			8	80	340
North Fork Blue	do	do			4	35	242
Smoky Hill	Kansas	Kansas			7	59½	442
Solomon	Smoky Hill	do			11	98½	657
North Fork Solomon	Solomon	do			8	104	298
South Fork Solomon	do	do			2	17	114
Saline	Smoky Hill	do			6	72	100
Republican	Kansas	Kansas and Nebraska.			7	43	356
Prairie Dog	Republican	do			6	71	152
Sundry small streams	Kansas and tributaries	do			41	486½	1,408
Total Kansas river and all tributaries.					145	1,345	6,501

THE LA MINE RIVER.

Below the Kansas the first river worthy of notice is the La Mine, which drains an area of 2,700 square miles, situated in the western central part of Missouri. It enters the Missouri river in Cooper county, a few miles above Boonville. Ascending the river, it is found to divide about 10 miles above the mouth, one fork coming in from the south; while from the west it receives the Black Fork, which rises in the western part of Johnson county, and has a length by general course of about 65 miles.

The country drained by the La Mine is a rolling prairie, with a fair amount of timber along the streams. It is a rich agricultural section, with valuable resources also in the way of building-stone, coal, lead, and other minerals. The stream was not visited by me, and detailed information cannot here be given regarding it. A small grist-mill, using 5 feet head, is returned as taking power from the La Mine, and one, with 6 feet head, from the Black Fork. If we may judge from other streams in this section, the La Mine would probably furnish small powers for the greater part of the year, but cannot be considered a stream of any especial value.

Drainage areas, La Mine river.

Stream and locality.	Drainage area.
	Sq. miles.
Black Fork, at Houstonia, Pettis county	986
Black Fork, at mouth	1,492
South Fork, above Black Fork	1,185
Total, La Mine below junction	2,677
Total, La Mine at mouth	2,700

MOREAU CREEK.

This creek may serve as an example of some of the smaller streams of central Missouri. Rising in Morgan county, it flows easterly through Moniteau and Cole counties, entering the Missouri a few miles above the mouth of the Osage. It well illustrates how winding are some of the rivers of this state; although its entire length, by general course, is only 30 to 35 miles, yet 30 miles of its actual course lies within 6 miles of Jefferson City. It drains 384 square miles of country, rich in resources. The valleys are valuable for agriculture; the surface is thickly timbered with oak, ash, elm, hickory, walnut, sycamore, and cottonwood; while bituminous and cannel coal, lead, iron, zinc, copper, and building-stone occur more and more abundantly toward the headwaters.

This region is very hilly and is intersected by numerous small streams which run into the Moreau. The fall of the latter is stated to be 2½ to 3 feet per mile. Owing to the limited extent of its drainage area, the stream would not, probably, furnish continuous power to any but small mills. A small grist-mill is returned as taking power from it, with 9 feet head, in Cole county, but otherwise it is unemployed. In consequence of its tortuous course, there are points at which power might be developed by tunneling through a neck of land at a long bend. Such a site has been described to me by Mr. George B. Ransom, surveyor of Cole county. It is close to Jefferson city, in sections 28 and 29, township 44, range 11, and offers a good location for a mill. Mr. Ransom carried a line of levels over the bluff at this point, and found a fall of over 20 feet in the intermediate portion of the river.

THE OSAGE RIVER.

Below the Kansas river, the most important tributary of the Missouri, so far as concerns extent of country drained, is the Osage. Occupying the intermediate space between the La Mine and Gasconade, it comprises within its basin a large and valuable section of southwestern Missouri and southeastern Kansas, having a superficial area of about 15,300 square miles. The eastern portion of this section has a diversified surface, varying from the level alluvial bottoms of the streams to broken, hilly uplands; it is covered with a thick growth of timber, including various kinds of oak, elm, walnut, maple, ash, and many other varieties of trees. West as far as the Sac river the appearance of the country remains substantially the same, gradually, however, assuming more of the prairie character, and the quantity of timber somewhat diminishing; advancing still nearer the western boundary of the state of Missouri, timber disappears from the uplands, though it is still seen in heavy fringes along the streams, the surface of the country becomes more gently undulating, and we are in the midst of broad prairies which extend unbroken to the Rocky mountains.

The resources of southwestern Missouri are magnificent in quality, variety, and extent, but, owing largely to sparse settlement and imperfect means of communication, they yet lie comparatively undeveloped. Doubtless the chief in importance are the valuable minerals scattered lavishly over this portion of the Osage basin. First in abundance is iron, said to occur in large quantities in nearly every county along the Osage, and especially in the counties of Miller, Camden, Morgan, and Benton. The varieties of ore are principally limonite, red hematite, and blue specular, and thousands of tons are stated to lie on the surface of the ground in the shape of large bowlders. Bituminous coal is found all along the river, and in Morgan and Benton counties there are beds of cannel-coal. Lead is also scattered through this section, and deposits of zinc, copper, nickel, cobalt, and tin exist. There is an abundance of limestone and sandstone, suited to building purposes, throughout this part of Missouri, and kaolin and grit occur in some of the counties as valuable deposits. The formations of coal, limestone, and sandstone are continued through that portion of the Osage basin which lies in Kansas, but the metals are confined to the extreme southeastern corner of that state.

Aside from its resources of minerals, timber, and stone, the section of country drained by the Osage is rich agriculturally. The gently-rolling prairies of the western half, and in the eastern half the valleys and river bottoms, are splendidly adapted to the raising of corn, wheat, oats, tobacco, and various other staples. The rich grasses, including in the south the blue-grass, the abundance of timber and the numerous springs and small running streams, offer great advantages for stock-raising. The climate is healthful, with usually mild winters and but a small amount of snow and ice.

The principal fork of the Osage rises in the prairies of eastern Kansas, some 30 miles southwest of Topeka, taking thence a southeasterly course into Missouri. The Little Osage rises farther south in Kansas, runs easterly, and about 20 miles east of the Missouri boundary joins the main river. The latter is locally known as the "Marais des Cygnes" above the mouth of the Little Osage, but on the maps the Osage is recognized as extending into Kansas, and I assume its head to be at Osawatomie (mouth of Pottawatomie creek), and consider its continuation above that point to be the Marais des Cygnes. In Missouri the Osage pursues a winding course, with a general direction somewhat north of east, and reaches the Missouri river about 10 miles east of Jefferson City.

The country drained by this river is fairly well supplied with railroad facilities on the north side and toward the headwaters, though the lines usually run at right angles to the river's course; but to the south, in Missouri, the nearest roads are 20 to 60 miles away from the main stream. Navigation commonly extends to Tuscumbia, about 60 miles by river from the mouth, above which point there is considerable rafting of railroad ties and lumber.

In spring high-water boats ascend to Osceola, 221 miles from the mouth, and have even gone as high as Papinsville. The river has been surveyed or reconnoitered by government engineers up to Ottawa, Kansas, with a view to its improvement for navigation. The only satisfactory method of improvement seems to be by a system of locks and dams, but the expense of such a work would be so great that it is not thought it would be warranted by the commerce of this section for many years to come.

As early as 1850 or 1855 attempts were made by the state of Missouri to improve the river, and wing-dams were built on many of the shoals; they were not well located or properly constructed, however, and failed in their purpose. Since 1870 appropriations of $20,000 to $25,000 have been made in various years by the general government, and work has been directed to the building of cross-dams and training-walls, the clearing of the channel by scraping at the shoals, and the removal of rocks, snags, and leaning timber, with the object of obtaining a 2-foot channel at lowest stage of river.

The Osage runs through an alluvial bottom, in which it winds along, approaching first one bluff and then the other. Following the general trend of its valley, and neglecting the minor bends, it measures about 280 miles in length to the head of the Marais des Cygnes, but its actual length is probably at least 500 miles. The bed is generally gravel, especially on the shoals, though considerable sand is found in the quiet pools, and appears to be everywhere underlaid by rock at a depth of 5 or 10 feet. The banks are gravelly and stable, and range for the most part from 20 to 25 feet in height above low water, sometimes rising to 35 feet, and again falling to 18 feet. At Papinsville the Osage is, in a low stage, but a small stream, with a few inches of running water on the shoals, though in great freshets it is 20 feet deep. For several miles below the mouth of the Little Osage the main river is 150 feet wide at low water, 5 feet deep, clear, and with no perceptible current. Below the mouth of the Sac the width between banks is 350 to 400 feet, and steadily increases to the mouth, where it is about 1,000 feet.

Although this river makes a show of some importance to the eye, it is really only a chain of deep pools, connected by shoals having moderate fall. The amount of water flowing at a low stage is small, but difficult to estimate on account of the gravelly bed, which permits considerable water to leach along through it. I am informed by Captain O. H. Ernst, corps of engineers, from whom most of my information concerning this river was obtained, that the low-water discharge at Tuscumbia and below is assumed at 300 cubic feet per second. In the upper portion of the main river the volume has been estimated as low as 56 cubic feet per second, but cannot be accurately stated for the reason already given. The shoals connecting the pools are natural dams, being accumulations of gravel, causing contraction of the water-way both vertically and horizontally. Although it might seem easy at first glance to remove these natural dams and secure navigation, yet if it were done the pools would be drained and the stream much diminished in size.

From the engineers' surveys the slope of the river is found to be as follows:

Slope of the Osage river.

Section of river.	Distance between points.	Fall between points.	Fall between points.
	Miles.	*Feet.*	*Ft. per mile.*
Ottawa, Kansas, to state line	90⅛	121.75	1.35
Thence to mouth of Little Osage	56	42.70	0.76
Thence to Osceola	40⅜	25.75	0.52
Thence to Rainy creek, in Camden county, Missouri	91	77.60	0.85
Thence to Tuscumbia	70⅛	65.60	0.92
Thence to mouth of Osage	59⅛	25.50	0.43
Total, Ottawa to mouth	417	358.30	0.86

Tuscumbia is just above the influence of backwater from the Missouri.

Although the Osage is but a small stream at low water, it becomes a mighty flood during freshets. It is subject to great and rapid rises, and also to long periods of drought. The highest recorded rise at the mouth is 39 feet, and was not due to backwater from the Missouri, which is itself sometimes set back by the Osage in very high water. In 1880 a gauge was established at Tuscumbia, some of the records of which are of interest as showing the character of the river. In August, 1880, the gauge stood at about zero, or low-water mark. Early in September it reached about 9 feet, the river rising 7 feet on September 3. October 1 the reading was 0.05 foot; October 10, 4.95 feet, and October 22, 0.50 foot. The stream remained low and frozen most of the time till the 7th of February, when it began to rise and broke up the ice. It rose nearly 15 feet in a few days, or from zero to 14.95 feet (February 10). April 1 it was down to 5 feet, and through that month gradually fell.

That portion of the river between Osceola, Missouri, and Ottawa, Kansas, has been surveyed and reported on by Colonel James H. Simpson, corps of engineers. (*a*) As before stated, the local name above the Little Osage is

a Report dated February 13, 1879; not published.

"Marais des Cygnes", meaning "seven marshes", and it is said that marshes seems an appropriate term to apply to the river at a low stage. The survey by Colonel Simpson was made in the dry season, when there was practically no water flowing, at least the velocity was so small that it could not be measured, and no instrumental gauging was attempted. The banks in this part of the river average 25 feet in height above low water. Occasional limestone or sandstone bluffs are met, varying from 40 to 200 feet in height, but always with an alluvial bottom opposite. Here, as well as in the lower river, the freshet rise is large. In the rise of 1875 the river above the Little Osage was unusually high; the height at Ottawa as 35 feet above low water, and at Papinsville, Missouri, it was 25 feet.

There is one dam on the Marais des Cygnes and there are three on the Osage, located as follows: Franklin county, Kansas, one with 8 feet fall; Day's dam in Miami county, 8.2 feet fall; Trading Post dam in Linn county, 5 feet fall; Haymaker's dam in Bates county, Missouri, 8.6 feet fall. From what has been said, I think it is evident that the main river has practically little or no value for water-power. The only points in its favor are a firm bed and high banks. On the other side are to be placed its width, its extremely small volume at certain seasons, and its liability to sudden and very heavy rises, which must, at times, submerge its banks. It has scarcely any current at a low stage, its fall is slight, and there would be great trouble to mills from backwater. The country through which it runs is sparsely settled, and there are no important towns on its course. Roscoe, Osceola, and Warsaw enjoy a small local trade, but the latter place, the largest of the three, returns only about 500 inhabitants.

Concerning the tributaries of the Osage I have but little information, but they are undoubtedly much better suited to use for water-power than the main river. Most of them must run very low at times, but for the greater part of the year they could probably be relied upon for moderate powers. The Sac is one of the most important of these. It joins the main river from the south, a short distance above Osceola, and is said to have nearly as large a low-water discharge as the Osage at their junction. It is used for power by a considerable number of small flouring- and grist-mills, more than are found on any other tributary of the Osage.

The Niangua is another important branch, and is well sustained by springs. Concerning one of these it is said: (*a*) "No water-power can excel that at Bryce's spring, on the Niangua. It discharges about 11,000,000 cubic feet of water per diem, with no perceptible variation of temperature or quality." Its temperature is about 60° Fahrenheit; no ice ever forms, and the flow is very steady. The Gravois and Pomme de Terre are also used for power, but are of less importance than the Sac and Niangua.

The average rainfall on the Osage basin is, approximately, 12 inches in spring, 14 in summer, 9 in autumn, 6 in winter, and 41 for the year. The yearly amount shows great fluctuations in the upper basin and its vicinity, ranging, in a term of years, from 20 to 63 inches at Fort Scott, and from 38 to 88 at Olathe, Johnson county, Kansas. The volumes assumed for a low stage by the government engineers correspond to a rate of discharge varying from less than 0.01 cubic foot per second per square mile of drainage area, for the upper river, to about 0.02 foot for the lower. This rate of discharge is very small, being not more than one-sixth the low-water rate of the Gasconade to the east; and, in fact, probably no greater than for the James river, of Dakota, where the annual rainfall is less than half as large as here. It must be explained, I think, by the occurrence of long periods of drought; by the great evaporation consequent upon the open, prairie character of the country toward the headwaters, and the long, winding course and sluggish flow of the river; and, perhaps, by unusually large loss from percolation through the underlying formations and deposits.

Estimated volume and horse-power of the Osage river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Below Little Osage	5,631	70	80	140	159	270	367
Below Sac	8,348	120	136	210	239	420	477
Baker	8,632	120	136	220	250	440	500
Warsaw	11,732	210	239	330	375	650	738
Linn creek	13,582	260	295	370	420	740	841
Tuscumbia	14,286	300	341	410	466	830	943
Mouth of river	15,262	300	341	460	523	920	1,045

NOTE.—Drainage area of the Marais des Cygnes at Ottawa, 1,253 square miles; Osage at La Cygne, 2,769 square miles; Little Osage, 1,723 square miles; Sac, 1,932 square miles; Pomme de Terre, 980 square miles; Grand, 1,040 square miles; Niangua, 1,011 square miles.

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a Barnes' *Commonwealth of Missouri.*

Power used on the Osage river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Auglaize	Osage	Missouri	Miller	Flour and grist	1	4	8
Do	do	do	Camden	do	2	20	29
Wet Auglaize	Auglaize	do	do	do	1	6	19
Do	do	do	Miller	Woolen	1	5	8
Small streams	Niangua	do	Camden	Flour and grist	3	61	46
Do	do	do	Laclede	do	1	20	200
Do	do	do	Dallas	do	3	40	43
Do	do	do	do	Saw	1	4	20
Pomme de Terre	Osage	do	Benton	Flour, grist, and saw	1	7	50
Do	do	do	Polk	Flour and grist	1	6	20
Do	do	do	do	Saw	1	10	60
Sac	do	do	Saint Clair	Flour and grist	1	7	20
Do	do	do	Cedar	do	1	8	20
Do	do	do	Dade	do	1	6	82
Small streams	Sac	do	Cedar	do	1		34
Do	do	do	Polk	do	1	8	45
Do	do	do	Dade	do	3	24	98
Do	do	do	do	Flour, grist, and saw	1	6½	22
Do	do	do	Lawrence	Flour and grist	4	70½	75
Do	do	do	Greene	do	8	109½	131
Osage	Missouri	do	Bates		1	9	
Do	do	Kansas	Linn	Flour and grist	1	5	25
Do	do	do	Miami		1	8	
Marais des Cygnes	Osage	do	Franklin	Flour and grist	1	8	50
Small streams	do	Missouri	Miller	do	1	20	16
Do	do	do	Morgan	do	2	45	28
Do	do	do	do	Woolen	3	50	26
Do	do	do	do	Flour, grist, and saw	3	47	58
Do	do	do	do	Saw	1	5	10
Do	do	do	Benton	Flour and grist	1	16	8
Do	do	do	Henry	do	1	7	12
Do	do	Kansas	Miami	do	1	9	20
Do	do	do	Linn	do	3	58	43
Do	do	do	Anderson	Saw	1	6	15
SUMMARY.							
Osage	Missouri	Kansas and Missouri.		Flour and grist	3	22	25
Auglaize and tributaries	Osage	Missouri		do	5	35	64
Small streams	Niangua	do		Flour and grist (1 saw-mill).	8	134	309
Pomme de Terre	Osage	do		Flour, grist, and saw	3	23	136
Sac and tributaries	do	do		Flour and grist (1 saw-mill).	21	230½	527
Small streams	do	Missouri and Kansas.			18	277	286
Total, Osage and tributaries.					58	730½	1,347

THE GASCONADE RIVER.

Piney, Lick, and Osage forks, heading in southern Missouri, come to a final union in Pulaski county, where they make up the main Gasconade river, which then pursues a northeasterly direction to the Missouri. From the junction of the forks to the mouth the distance by general course is about 60 miles, but accurately measured is probably twice as great. The basin of the river comprises a total area of 3,667 square miles. The country along its course is sparsely settled by a thrifty class of German farmers; but there are no important towns, and the combined population of those counties, from Pulaski down, which touch the stream directly, is only about 30,000. The Missouri Pacific railway crosses the river near its mouth, and a few miles below the mouth of Piney Fork there is a crossing of the Saint Louis and San Francisco line, but the intermediate section is without railroad facilities.

The country lying at the headwaters of the Gasconade is, to a considerable extent, an elevated table-land belonging to the Ozark range of hills, and has an elevation of 1,200 to 1,500 feet above the sea. It has an irregular surface, which becomes very rough and broken along the streams. The latter are kept steadily supplied by a great number of springs, many of which are of large size, and are used for power to a small extent by flouring- and grist-mills. They are bordered by alluvial bottom-land, varying in width from a few hundred feet to half a mile, and very productive. The soil of the bottom-land and of much of the upland in this part of Missouri yields good crops of corn, wheat, rye, oats, and tobacco. The ridges are covered with a thick growth of oak, while in the valleys there are extensive tracts of pine, and a variety of other trees, including ash, sycamore, cottonwood, elm, hickory,

walnut, and maple. The country is well supplied with limestone and sandstone, and has valuable mineral resources of lead, iron, and zinc. The abundance of nutritious grasses, timber, and clear water renders it very favorable to stock-raising.

Under the direction of Major Suter, the Gasconade has been examined and reported upon by Mr. Thomas Y. Johnston, assistant engineer, to whom I am indebted for much information concerning the stream. The examination extended over that portion between the mouth and Indian Ford, near Vienna, and was made with a view to improving the navigation. From the report (*a*) it appears that at present there is no navigation, though with a moderate rise boats are enabled to ascend as far as the Saint Louis and San Francisco railway crossing. An active business is done in rafting lumber and ties, and it is estimated that 80,000 of the latter were floated down in 1879. From Indian Ford to the mouth, a distance of 78¼ miles, there is a fall of 108 feet, or about 1.4 feet per mile. The river is a succession of pools and shoals, with a mean channel width at low water of about 200 feet. The chief hinderances to navigation were found to be an insufficient depth of water on the shoals, and the presence of snags at various points. It was proposed to remove the latter, and to rectify and deepen the channel by the construction of low dikes, the estimated expense of the work being $50,000. In June, 1880, $5,000 was appropriated by Congress for the removal of snags.

The valley of the stream averages about half a mile in width, and is bordered by bluffs 100 to 200 feet high. The bed is usually gravel on the shoals, with considerable sand and mud in the pools, and is underlaid by rock at an estimated depth of 10 to 30 feet. The banks are about 20 feet high on the lower river, and show a deposit of alluvial soil, with sand and gravel underneath. The rock occurring along the stream is mainly limestone and sandstone. The Gasconade is subject to sudden and great spring freshets. In the portion surveyed the ordinary oscillation is stated as 15 feet, with a maximum of 23 or 24 feet. At Rolla it was said that in its upper course the river rises 20 feet or more above low water, sometimes coming up 7 or 8 feet in a single day. In very high water it overflows the banks and submerges the valley from bluff to bluff, though such a stage lasts but a short time.

The river is almost entirely unused for power. On the upper course a flouring- and grist-mill is returned for Pulaski county, having 9 feet head and 18 horse-power. Below Vienna there is a small saw- and grist-mill at a locality known as Prior's Bend, and situated on a slough. By tunneling, at a point above the mill, from the upper side of the bend, across the neck to the head of a small creek which puts into the river, a fall of 8.25 feet can be obtained. At Powell's mill, not now in use, there is a dam and some four feet fall. On the portion of the river that has been surveyed the shoals have but a slight declivity, and with the exception of Prior's Bend the maximum fall on any one is only 3 feet. In its upper waters the Gasconade is a much more rapid stream; in the vicinity of Waynesville it is 300 feet wide, with shoals every quarter or half mile. The bed is of rock and gravel, and the banks usually rise in rocky cliffs on one side, with a strip of sand or rich loam on the opposite shore; the freshet rise is about 6 feet. The river is in this section very winding, and forms numerous long bends with narrow necks. One of these bends, located in section 9, township 36, range 12, is said to be 15 miles in length, though the distance across the neck is not more than a quarter of a mile. The intervening fall is estimated to be at least 75 feet.

The volume of the Gasconade at extreme low water, below Vienna, is given by Mr. Johnston as about 450 cubic feet per second, equivalent to 0.14 cubic foot per second per square mile of drainage area. I quote from a letter by that gentleman, giving valuable information regarding the discharge and oscillations of the river:

The discharge of the Gasconade river at any point is derived from two sources—one the surface drainage, the other the subsurface drainage. The smallest value of the latter constitutes the low-water discharge (loss by evaporation and seepage not being considered), since at time of lowest water there is no surface drainage. As to the volume of this subsurface drainage, the smallest in the lower river has alone been measured, and amounts to 450 cubic feet per second; nothing is known as to what its maximum volume may be, except what is embodied in the assertion that the subsurface drainage increases to some extent after rains and melting of snows, in a way varying with the duration, amount, and extent of these phenomena. The amount of water derived from this source diminishes, of course, as one ascends the river; however, in low water, in the lower hundred miles of the river, it is very probable that, in consequence of evaporation and seepage, this diminution of discharge in ascending the river is changed to a diminution of discharge in descending. This is because at time of low water there is scarcely any subsurface drainage in the lower part of the river valley.

The component of the discharge derived from surface drainage exists only at times when the river is above low water—at times of rains and melting of snows. When obtained from heavy rains of short duration the water passes off very rapidly, owing to the steep slopes of the tributaries; so rapidly, in fact, that the river will rise as much as 10 feet in twenty-four hours. When derived from slow, protracted rains, or melting of snows, the water passes off nearly as rapidly, but the supply being slow and protracted the river will rise more slowly and less high, and the rise last longer. Should a protracted dry season have preceded the rains, a considerable volume of water will be at first absorbed by the ground; a part of which augments subsurface drainage, and the rest is evaporated.

The extreme range between high and low water in the Gasconade varies from 20 to 25 feet, according to the physical features of the river bed where the oscillation is measured. The discharge corresponding to highest water is roughly estimated at about 35,000 or 40,000 cubic feet per second. The total annual discharge of the river varies largely from year to year; also the length of time during which the river can be found at any given stage varies very much. Thus in a year of frequent and slow rains, while the river never attains a great height, still it remains above ordinary low water all the year; the stream would, of course, oscillate in unison with the variation in frequency and amount of rains; such a season occurs once in a while. Going to the other extreme, very heavy rains may occur early in the spring, after which the river rises very high, and then rapidly recedes toward low water, and remains in that vicinity all the rest of the year, very low water probably existing late in the fall; such seasons occur occasionally. All grades exist of variations of method of discharge between these extremes, the tendency being primarily toward high waters early in the spring, and secondarily in the late fall, with low stages intervening. Considerable rises about May are not infrequent. The lowest water almost always occurs in the fall of

a See *Report Chief of Engineers for* 1880.

the year—usually in late October or November. This is rational in consideration of the fact that surface drainage almost always amounts to nothing in the fall, and consequently subsurface drainage tends to exhaust itself. It is in virtue of the subsurface drainage that the river does not run dry, the resistance to draining rainfall by subsurface channels being great, and hence protracting the drainage. The same cause tends to preserve the constancy of low-water discharge.

It appears to me that the surface drainage operates against milling interests for several reasons, at least. Its amount and time of duration and occurrence cannot be relied upon. If a dam is used to gain the head of water (its height being limited on account of prevailing overflow), that head diminishes as the river rises in such a way that at high water, if the dam is in height but half that of the normal oscillation of the river, the head will be nearly obliterated. If lateral canals are used for gaining head of water they will have to be several in number at different levels, or else one very expensive deep one with at least one high artificial bank, with sluices at either end extending above high water. If tunneling through the hills across the neck of a bend in the river is resorted to the most favorable plan for using volume of surface drainage is adopted; but the first objection still holds—unreliability of surface drainage.

On the other hand, subsurface drainage appears to be the most useful for milling purposes. Its volume and variation in volume approach nearer to constancy, and, I think, are capable of being approximately determined, if the necessary physical features of the stream in question are observed. As to the Gasconade river no observations have been made that point to determining any other feature of this subsurface drainage than its minimum amount, 450 cubic feet per second. That this minimum amount *sometimes* lasts several months in the year is tolerably certain, and that during the rest of the year it is more. That this minimum amount is sometimes *not* reached at all during a whole year is quite certain. But nothing is known as to the average annual duration of it, and consequently and similarly nothing is known of the average duration of higher stages of the river.

From what has been said it is evident that the Gasconade might be made to yield important powers, although works designed for that purpose would need to be substantial and expensive. In its favor are to be mentioned the firm gravelly bed; banks of moderate height, though usually lower on one side than the other; and a well-sustained and considerable low-water volume. The railroad facilities, however, are not good at present; the greater part of the main river presents no shoals of importance; and the valley is often badly overflowed. The large amount of rafting done on the stream would also threaten injury to dams. It was stated to me that the owners of saw-mills in this section regard the use of the river for water-power as practicable, but consider that it would be too expensive for their business, and prefer to employ portable engines. Probably the forks which go to make up the Gasconade would be found better suited to development than the main river.

The rainfall on the basin of this river is, approximately, 12 inches in spring, 11 in summer, 8 in autumn, 7 in winter, and 38 for the year. I estimate the volume and horse-power as in the table below:

Estimated volume and horse-power, Gasconade river.

Locality.	Drainage area.	LOW WATER, ORDINARILY DRY YEAR.		LOW WATER, AVERAGE YEAR.		AVAILABLE 10 MONTHS IN AVERAGE YEAR.	
		Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second	Theoretical horse-power, 10 feet head.	Volume, cubic feet per second.	Theoretical horse-power, 10 feet head.
	Sq. miles.						
Osage Fork, above Lick Fork	649	60	68	110	125	160	182
Lick Fork, above Osage Fork	744	70	80	130	148	180	204
Total below junction	1,393	130	148	240	273	340	386
Above Piney Fork	1,915	260	295	340	386	470	534
Piney Fork	752	70	80	130	148	180	204
Total below Piney Fork	2,667	330	375	470	534	650	738
At Vienna	3,181	430	488	560	636	780	886
At mouth	3,667	450	511	650	738	900	1,022

Power utilized on the Gasconade river and tributaries.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Gasconade	Missouri	Missouri	Osage	Flour and grist	1	4½	68
Do	do	do	Pulaski	do	1	0	18
Piney Fork	Gasconade	do	Texas	do	3	25	35
Do	do	do	do	Saw	1	4	10
Do	do	do	do	Woolen	1	5	6
Small streams	Piney Fork	do	Pulaski	Flour and grist	2	60½	51
Do	do	do	Phelps	do	3	30½	40
Do	do	do	Texas	do	2	44	26
Lick Fork	Gasconade	do	Wright	do	1	7	8
Wood's Fork	Lick Fork	do	do	do	1	4	6
Osage Fork	Gasconade	do	Laclede	do	3	13	34
Spring	do	do	Maries	Woolen	1	14½	35
Do	do	do	do	Flour and grist	3	32	49
Total					23	253	386

Summary of power utilized on the tributaries of the Missouri river.

Stream.	Tributary to what.	State.	County.	Kind of mill.	Number of mills.	Total fall used.	Total horse-power of wheels.
						Feet.	
Sundry streams	Missouri	Montana territory			24	715½	654
Do	do	Wyoming territory			2	25	38
Small streams	do	Dakota territory			4	51	127
Dakota	do	do			6	47½	228
Vermillion	do	do			5	35	133
Big Sioux and tributaries	do	Dakota territory (mainly)			10	159½	673
Floyd	do	Iowa			2	22	61
Little Sioux and tributaries	do	do			21	213½	907
Soldier	do	do			2	13	57
Boyer and tributaries	do	do			9	79½	242
Platte and tributaries	do	Nebraska and Colorado			84	1,069½	4,157
Little Nemaha	do	Nebraska			9	99	228
Small streams	do	Iowa			7	82	234
Do	do	Nebraska			21	209½	622
Nemaha and tributaries	do	Nebraska (mainly)			14	150½	404
Nishnabatona and tributaries	do	Iowa (mainly)			23	219	701
Big Tarkio and tributaries	do	Missouri and Iowa			5	46	133
Nodaway and tributaries	do	do			18	159	449
Platte and tributaries	do	do			23	202	869
Kansas and tributaries	do	Kansas and Nebraska			145	1,345	6,561
Grand and tributaries	do	Missouri and Iowa			37	200	1,063
Chariton and tributaries	do	do			6	50	215
Osage and tributaries	do	Missouri and Kansas			58	730½	1,347
Gasconade and tributaries	do	Missouri			23	253	386
Small streams	do	Kansas			1	15	50
Do	do	Missouri			16	218½	350
Total for the Missouri river basin					581	6,584	21,012

V.—THE EASTERN IOWA SLOPE.

The section thus designated lies east of the water-shed line, which, passing southerly through Iowa, divides the basin of the Mississippi from that of the Missouri. The principal streams are as follows:

	Square miles.
Maquoketa river, drainage area	1,921
Wapsipinicon river, drainage area	2,568
Iowa river, drainage area	12,519
Skunk river, drainage area	4,409
Des Moines river, drainage area	14,578
Total	35,995

I omit from this list the Turkey and Upper Iowa rivers, which properly belong to eastern Iowa, but were not within the district assigned to me for examination.

The Upper Des Moines and Cedar rivers drain limited areas in southern Minnesota, and the lower valley of the Des Moines includes a narrow strip in northeastern Missouri; otherwise the basins of the streams to be considered are within the state of Iowa. The surface is usually an undulating prairie, but in some localities, as to the west of Fort Dodge, closely approaches a level; there is only a small percentage of timber, and that exists mainly as fringes along the water-courses. Scattered over the upper basins of the rivers are many natural ponds of small size, and occasionally there is a lake of several square miles area. As shown by the courses of the streams, the country has a general declivity to the southeast; from Spirit lake, in the northwest, to the mouth of the Des Moines, the average amount of this declivity is 4½ feet per mile. The mean elevation of the surface may be taken as 900 to 1,000 feet above sea-level, the altitude of various points being shown in the accompanying table.